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THE UNIVERSITY OF ALBERTA

CONFIRMATION, CORROBORATION AND ACCEPTABILITY

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled CONFIRMATION AND ACCEPTABILITY submitted by Jerome Edmond Bickenbach, in partial fulfilment of the requirements for the degree of Master of Arts.

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ABSTRACT

In this thesis we take the general question of acceptability to be that of devising selection criteria a scientist could employ when faced with a choice between two or more competing hypotheses. We show that there are at least two different senses of 'acceptability' as understood in this context (which we label A-acceptability and B-acceptability), and that it is important to distinguish between them. In terms of what we take to be the philosophically more interesting sense of 'acceptability', namely A-acceptability, two general questions are argued to arise with regard to the decision situation faced by the scientist: I. Which hypothesis should I pick given the evidence which is at hand? and II. Which hypothesis should I pick when the evidence at hand supports, equally well, both hypotheses? With these two questions in mind, we proceed to consider two approaches to the explication of selection criteria based on the notions of confirmation and corroboration. The two approaches we consider are those of Carl Hempel and Karl Popper. We first attempt to discover the motivations for each approach and to formulate versions of each which are comparable. Once this is done, we discover that each approach generates different answers to the two crucial questions I and II. Next we attempt to show that both approaches are inadequate for several reasons. We suggest that these approaches, and especially Popper's, may be seen as attempts to answer the question of B-acceptability, and conclude by reconsidering the problem of acceptability in light of the failure of these two approaches.

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CHAPTER I

INTRODUCTION

If a scientist is faced with the problem of choosing between two or more hypotheses, what should he use as a selection criterion? This question forms the background to the question of the *acceptability* of scientific hypotheses. We shall here be concerned to delimit the problem of acceptability in terms of the failures of two sorts of general approaches to the establishment of selection criteria. By critically examining these two approaches we hope to isolate the inadequacies which inflict both of them; these inadequacies will serve to make us more aware of the complexities involved in the question of selection in particular and hypothesis acceptance in general. Furthermore, we shall attempt to show that there are two different senses of the concept of acceptability and that it is necessary to distinguish between them. Our first task, then, is to develop these two senses.

We begin with a recent attempt to indicate that acceptability is a concept which applies to different aspects of scientific methodology. In an article titled "Changes in the Problem of Inductive Logic,"[1] I. Lakatos has attempted to isolate three contexts of the acceptance of hypotheses. In the context of "acceptability_1" scientific hypotheses are evaluated with regard to their "testworthiness" (or, "boldness"), that characteristic of hypotheses which determines, before the results of testing are available, whether or not a hypothesis is suitable for further consideration. A hypothesis is accepted in the context of "acceptability_2" if it is "well-tested" and has, furthermore, "proven its mettle" to the extent that the risk of further research in its terms is justified. Lastly, a hypothesis is accepted in the context of "acceptability_3" if the results of testing have indicated that the hypothesis may be viewed to be assured of future success, i.e., it has the status of a law. All three contexts are seen by Lakatos to be functions of the stage of investigation during which the decision to accept or reject a hypothesis is made.

Hence, the same hypothesis could be accepted$_1$, because of certain formal properties it exemplifies with regard to its "testability", and later accepted$_2$, if it has survived preliminary testing, and later still accepted$_3$, if we are confident of its future success. The value of Lakatos' distinctions can be seen in the difference between acceptability$_1$ and the other two sorts of acceptability. On the one hand, we see a decision to accept a hypothesis made prior to the testing of that hypothesis, and on the other hand we see decisions made which are based upon the results of tests. We shall make use of this two-fold contextual distinction in what follows.

We can frame the distinctions we wish to make in terms of the supersession of one more or less entrenched hypothesis by another hypothesis. A clear example of this supersession can be found in the case of the hypotheses of Harvey and Galen. Galen's hypothesis concerning the flow of blood in the bodies of animals (i.e. continuous dispersal from the liver) was, prior to Harvey's work, a hypothesis which was accepted in some strong sense (e.g. accepted$_3$). Harvey's hypothesis presented the familiar notion of blood circulation, and was put forward in order to overthrow and supersede the more "classical" view offered by Galen centuries before. Here we have the most dramatic example of a decision situation: Two rival hypotheses are put forward, both can account for the phenomena, and only one can be accepted. A decision situation of this sort forms the context of hypothesis selection which is a significant part of the methodology of science. Harvey's hypothesis was found to account for all the phenomena accountable by Galen's view as well as much more, and consequently Harvey's hypothesis was accepted and Galen's view was rejected. Some philosophers of science seem to have this sort of example in mind when they speak about the acceptability of hypothesis. (Hence Karl Popper occasionally speaks of accepting hypotheses as the result of "natural selection," the ability to survive confrontations.[2]) It is not necessary to view the decision to accept a hypothesis as a matter of the complete adoption of it and the complete rejection of all other, competing, hypotheses: The confrontation between Harvey's hypothesis and Galen's constitutes a fairly rare phenomenon in the history of science. It is more usually the case that reasons are supplied which indicate that one hypothesis is more acceptable than another, although these reasons are not sufficient to wholly reject the latter hypothesis.

We will refer to the sort of acceptability outlined above as A-acceptability. And we will recognize when the question of the A-acceptability of a hypothesis is being asked by the following characteristics of the decision situation: (1) The decision-maker must designate which of the two (or more) hypotheses is more acceptable, i.e., he must choose between alternative hypotheses; (2) the rival hypotheses have been tested, neither of them have been refuted, and they have been shown to be viable alternatives. Hence, the question of A-acceptability presupposes that there is a need for a choice between rival hypotheses. However, the decision to A-accept a hypothesis need not lead to the complete rejection of the alternative hypotheses--the decision situation given by A-acceptability often involves rival hypotheses which are such that one offers only a slight and subtle modification of the other. Moreover, it is not realistic to suppose that the choice is always a permanent one, or one which is unanimously held by the scientific community.

A-acceptability always involves a comparison, i.e., it generates a relation which may be said to hold between rival hypotheses: "Hypothesis A is more A-acceptable than hypothesis B." Implicit in Lakatos' distinctions is, however, another sort of acceptability. Although it is clear that Lakatos' acceptability$_2$ suggests the confrontation between rival hypotheses which is the primary characteristic of our A-acceptability, still acceptability$_1$ is a quite different notion. A hypothesis may be accepted$_1$ without being tested and furthermore without being compared with another hypothesis. It would be appropriate in terms of this sense of acceptability to say that Harvey's hypothesis was acceptable before the evidence had been brought forward, and before it was considered to be a rival view. We must now attempt to isolate this second sense of acceptability.

When Lakatos suggests that a sense of acceptability can be applied to hypotheses in virtue of their being worthy of serious investigation[3], he is noting that there is a sense in which to call a hypothesis "acceptable" means that it possesses certain qualities which stand as reasons why it is a viable hypothesis, or indeed a viable alternative to a well-established hypothesis. In this sense we could say that Harvey's hypothesis was acceptable but that another (e.g. a hypothesis which asserted that the movement of blood in animals is illusory) was not acceptable, although neither hypothesis had been tested. A hypothesis is accepted in this sense if it can be determined that it has the capacity to be a viable and effective means of explaining phenomena.

Acceptability in this sense--we will call it B-acceptability--is strikingly different from A-acceptability. It might be difficult to see why a scientist would be interested in B-acceptability: When would a scientist be concerned with a hypothesis before it has been tested? For Harvey, it was the results of certain tests which impressed upon him the need for another picture of the movement of blood. Furthermore, when would the scientist be concerned with the capacity of a hypothesis to be an effective explanatory tool? In short, what is the decision situation of B-acceptability, in what context do we ask whether a hypothesis is B-acceptable or not?

We will understand the question of B-acceptability of hypotheses to be this: Can we devise a set of general qualities of hypotheses which we could employ to determine when a particular hypothetical proposition is, or is not, a scientific hypothesis worthy of consideration. Scientists are usually not concerned with questions like this; but philosophers who direct their attention to the analysis of what I. Scheffler has called "structural terms"[4] (e.g. "evidence," "explains," "predicts," and "hypothesis") are. So, whereas the scientist would merely reject out of hand a hypothetical assertion like "The movement of blood in animals is an illusion," the philosopher might be concerned to note that this "hypothesis" does not admit of falsification, and therefore is not acceptable.

Although these two notions of acceptability are different, there is in fact a direct connection between them: The qualities which are isolated with respect to the B-acceptance of hypotheses may be used as selection criteria for the A-acceptance of hypotheses. For example, if we choose to consider "simplicity" as a guideline for B-acceptance, then we may employ the relation "h_1 is simpler than h_2" as a selection criterion. Or, if perspicuity is the quality we wish to employ for B-acceptance, the relation "h_1 is more perspicuous than h_2" may serve quite well as a selection criterion. (This transition will not always work, since some qualities of hypotheses (e.g. internal consistency) are selection criterion as they stand, and need not be recast as comparative notions, while other qualities (e.g. compatibility with existing hypotheses) would not serve as selection criteria at all.)

In this paper we will restrict our attention to the quality of "confirmability," the capacity of a hypothesis to accord with evidence. We may understand "confirmation" to be a relation which holds between evidence and hypotheses such that the presence of the former serves to support or establish the latter. More generally, confirmation may be understood as simply a relation between actual or potential evidence and hypotheses. As a selection criterion, this quality of confirmability will be viewed as a relation between two hypotheses in terms of some set of potential evidence statements, such that one hypothesis is said to be "more confirmable" than the other.

In this paper we will be investigating two sorts of "confirmatory logics." Our concern will be to show that neither logic of confirmation is adequate as a formal selection criterion. We may first designate an adequate selection criterion to be one which is in accord with the intuitions that scientists follow when faced with a problem of A-acceptance. Hence an adequate selection criterion is one which is workable, one which scientists do use, or could use successfully. Secondly, we can understand an adequate formal selection criterion to be one which is a satisfactory explicatum, where the explicandum will be an adequate selection criterion. A satisfactory explicatum of a selection criterion is one which judges as preferable just those hypotheses which are intuitively preferable. (Although this characterization of a "satisfactory explicatum" is suitable it is somewhat too strong, and consequently we shall assume in what follows the weaker claim, namely a satisfactory explicatum of a selection criterion is one which does not judge the intuitively less preferable hypothesis to be at least as preferable as the intuitively preferable hypothesis.) We may assume that confirmation (i.e., the relation " . . . is more confirmable than . . .") is an adequate selection criterion. Our course of action will be to question the adequacy of both confirmatory logics as satisfactory explicata.

We are considering A-acceptability to be the important notion to investigate, and we will proceed to examine this sense of hypothesis acceptance. The two confirmatory logics which will concern us are Carl Hempel's Satisfaction Criterion and Karl Popper's Theory of Corroborability. Our primary concerns will be to discover the motivations for each view of confirmation and to formulate versions of these views which are comparable as approaches to the explication of confirmation. The first step towards making these approaches comparable involves us in a three-way conceptual distinction to which we now turn.

The distinction between classificatory, comparative and quantitative conceptions is due to Rudolf Carnap.[5] For a simple example of these distinctions we may consider the following expressions:

(1) A is warm.
(2) A is warmer than B.
(3) A is r degrees Fahrenheit.

In a discussion of the temperature of A we might find ourselves saying any one (or all three) of the above. If we utter (1) we are classifying or qualitatively describing A. With (2) we are comparing A's temperature with B's; and with (3) we are giving a precise (numerical) designation of A's temperature. The connection between expressions (2) and (3) is clear enough; for, given a metric (e.g. the Fahrenheit scale), the comparing of two objects is a natural and simple procedure.

Expression (1) is, however, clearly qualitative.

In a similar manner, as Carnap has argued, we may think of the relation of confirmation in either of three ways:

Classificatory: "h is confirmed by e."

Comparative: "h is more strongly confirmed by e, than h' is confirmed by e'."

Quantitative: "The degree of confirmation of h, on the basis of e, is r."

Rather than the tetradic comparative relation which Carnap gives we will assume that the comparative notions important in later chapters are dyadic, e.g., "h_1 is more confirmed than h_2."

In order to, on the other hand, make Hempel's classificatory conception of confirmation and Popper's quantitative theory of corroboration comparable as approaches to the explication of confirmation, and on the other hand, to fit Hempel's conception of confirmation into the framework of A-acceptability, we will make the following moves in Chapters II and III:

(A) We will extrapolate beyond Hempel's original work to form a comparative conception of confirmation which is in the spirit of Hempel's conception of classificatory confirmation (this extrapolation will be called the "Confirmatory Framework").

(B) We will take the necessary measures to form a comparative version of Popper's quantitative notion of corroboration and isolate the central ideas found in his corroborability functors.

We may now distinguish between two questions which arise with regard to the decision situation of A-acceptability:

I. Which hypothesis should I pick given the evidence which is is at hand?

II. Which hypothesis should I pick when the evidence at hand supports, equally well, both hypotheses?

We will find that these questions are answered in quite different ways by the Confirmatory Framework and by Popper: To the first question, the Confirmatory Framework answers that we should pick the hypothesis which is more confirmed to date; and Popper answers that we should pick the hypothesis which has withstood the severest tests which our past policy of attempting to refute the hypotheses has been able to devise. To the second question, the Confirmatory Framework answers that we should pick the hypothesis which has a better chance of being confirmable in the future; and Popper answers that we should pick the hypothesis which is "bolder," that is, more improbable relative to our background knowledge.

The differences between these two pairs of answers which are reflected in the different rules for A-accepting hypotheses come out most clearly for the case where one hypothesis entails the other. So, throughout our critical discussion of these two approaches we will be assuming that the entailment relation holds between the two rival hypotheses. For such cases, we will show that the Confirmatory Framework generates a policy which is weaker preferring, such that the entailed hypothesis is always at least as preferable as the hypothesis which entails it, whereas Popper's conception generates the opposite policy, that is, stronger preferring.

Having set up both conceptions of confirmation in the aforementioned manner in Chapters II and III, we will proceed to consider the question of the adequacy of these approaches with regard to the problem of A-accepting hypotheses. We will approach the question of adequacy from two perspectives. First, in Chapter IV, we will consider the adequacy of these two approaches with regard to the question of what should constitute confirming, or corroborating, evidence. Here we will bring to bear the issue of the "Paradox of the Ravens" attempting to show that (i) the Paradox is a significant problem for Hempel's original conception of confirmation, despite his arguments (and others) to the contrary, (ii) that the Paradox poses a problem for Popper's conception of corroboration as well, once again despite numerous arguments to the contrary by supporters of Popper, and (iii) that two attempts to solve the Paradox and vindicate Hempel and Popper do not succeed in vindicating them.

Secondly, in Chapter V, we will consider the adequacy of these two approaches with regard to the A-accepting of hypotheses and specifically with regard to the question arising out of the situation where present evidence does not settle, for either the Confirmatory Framework or for Popper, the question of which hypothesis to A-accept. Here we will be especially concerned about the completely different choices which come out of the two approaches:

If one hypothesis h_1 entails another h_2, then the Confirmatory Framework tells us to prefer the weaker hypothesis h_2, since every confirming instance of h_1 is also a confirming instance of h_2, and h_2 may have more besides. And given the same entailment between h_1 and h_2, Popper's theory tells us to always pick the strongest h_1, since it will be at least as falsifiable as h_2 and it may be more so.

In Chapter V we will argue that each preference policy is inadequate, that it is not always the case that either the weaker or the stronger hypothesis is more A-acceptable. We will also consider the issue of the function and nature of background knowledge as this information affects decisions to A-accept hypotheses, as well as problems with the languages in which each selection criteria is formulated. Our judgment will be that both confirmatory logics do not provide bases for adequate formal selection criteria, and furthermore that in the case of Popper's explicandum there is involved a confusion over A- and B-acceptability.

FOOTNOTES TO CHAPTER I: INTRODUCTION

1. I. Lakatos, "Changes in the Problem of Inductive Logic," in The Problem of Inductive Logic, ed. I. Lakatos. (Amsterdam: North Holland, 1968), pp.315-417.

2. Karl Popper, The Logic of Scientific Discovery (New York: Harper and Row, 1968), p.108.

3. Lakatos, p.376.

4. I. Scheffler, The Anatomy of Inquiry (New York: Knopf, 1963), p.5.

5. Rudolf Carnap, Logical Foundations of Probability (Chicago: University of Chicago Press, 1962), pp.8-11.

CHAPTER II

THE CONFIRMATORY FRAMEWORK

We will begin by presenting Carl Hempel's confirmatory logic which is based on a classificatory conception of confirmation. All of what we will present here is based on Hempel's article "Studies in the Logic of Confirmation,"[1] which is a more informal presentation of material found in an earlier article "A Purely Syntactical Definition of Confirmation."[2] Hempel's study is based on the view that it is a salient feature of empirical statements, and scientific hypotheses in particular, that they have the capability of being confronted by experiential findings. Consequently, it is important that we should be able to recognize "relevant evidence," i.e., evidence which either confirms or disconfirms a hypothesis. Hempel's task is therefore to explicate the relation between evidence and hypothesis such that the former can be said to confirm (or disconfirm) the latter, and specifically "to set up purely formal criteria of confirmation in a manner similar to that in which deductive logic provides purely formal criteria for the validity of deductive inference."[3]

In order to facilitate the construction of a logic of confirmation, Hempel proposes to widen the concept of "evidence" in the following manner: Evidence statements are to be construed as "observation reports" which are finite sets of "observation sentences." Given some "language of science" complete with an observational vocabulary, these observation sentences can be characterized as non-general (i.e. unquantified) expressions. Hempel's "language of science" is first-order predicate calculus without identity, the primitive predicates being agreed to be observation predicates. The domain of the relation of confirmation is seen by Hempel to be an infinite set of observation sentences each of which either asserts or denies that a given object has (or objects have) a certain observable property (or stand in an observable relation to one another). The range of the relation of confirmation, the hypotheses, are just sentences of this language.

Hempel prepares the ground for his confirmatory logic by noting and criticizing two conceptions of what constitutes confirming and disconfirming evidence. These conceptions are Nicod's Criterion and the so-called Prediction Criterion. As for the first informal explication of confirmation, Hempel points our attention to the following quotation from Jean Nicod:

> Consider the formula or the law: A entails B. How can a particular proposition, or more briefly, a fact, affect its probability? If this fact consists of the presence of B in a case of A, it is favorable to the law 'A entails B'; on the contrary, if it consists of the absence of B in a case of A, it is unfavorable to this law. . . Thus, the entire influence of particular truths or facts on the probability of universal propositions or laws operate by means of these two elementary relations which we shall call confirmation and invalidation.[4]

Given Nicod's condition for confirmation, it would follow that a hypothesis like "$(x)(P(x) \supset Q(x))$" can be said to be confirmed by a sentence which asserts that something, call it "a," has both the property "P" and the property "Q." Hence the sentence "$P(a)$ & $Q(a)$" would be confirming evidence for this hypothesis. Likewise, an object, say "b," which has the property "P" but lacks the property "Q," a state of affairs expressed by "$P(b)$ & $\sim Q(b)$," would be disconfirming evidence for the same hypothesis.

Hempel asserts that Nicod's Criterion is too narrow for two reasons. First, it only applies to hypotheses which are, in Hempel's language of science, expressible in the universal conditional form. Thus Nicod's Criterion would not be applicable to hypotheses which are either existential in form (e.g. "Poliomyelitis is caused by some virus") or mixed universal and existential in form (e.g. "For every toxin there is an antitoxin"). Furthermore, Nicod's Criterion would not be applicable to unquantified expressions, but these Hempel feels can also be confirmed or disconfirmed. Second, if we grant this limitation, Nicod's Criterion is not a necessary condition for confirmation as observation reports which confirm a hypothesis may not, on this definition, confirm logically equivalent hypotheses. For example, the sentence "$P(a)$ & $Q(a)$" confirms, by Nicod's Criterion, the hypothesis "$(x)(P(x) \supset Q(x))$" although it does not confirm the logically equivalent hypothesis "$(x)(\sim Q(x) \supset \sim P(x))$." Hempel argues that inasmuch as logically equivalent hypotheses "have the same content, they are different formulations of the same hypothesis,"[5] the fact that Nicod's Criterion fails to account for this represents a definite shortcoming.

In view of these two difficulties Hempel considers it to be a desideratum that a criterion of confirmation which suffices be one which is applicable to hypotheses of any logical form (I. Scheffler has termed this the "General Applicability Condition"[6]). And, in view of the second difficulty, it is required of any explicatum of confirmation that it satisfy the "Equivalence Condition" (see 8.22 below): Whatever confirms (disconfirms) one of two logically equivalent hypotheses, also confirms (disconfirms) the other. With regard to this requirement of adequate explicata of confirmation, Hempel argues that a logic of confirmation must take note of the function played by scientific hypotheses in such theoretical contexts as prediction and explanation. In these contexts scientific hypotheses serve as premises in deductive inferences, which are governed by the principles of formal logic. And in terms of these principles, a valid deduction will remain so if some or all of the premises are replaced by different but logically equivalent sentences.[7]

The second conception of confirmation Hempel considers is that suggested by A.J. Ayer in the following passage:

> . . . we have seen that the function of an empirical hypothesis is to enable us to anticipate experience. Accordingly, if an observation to which a given proposition is relevant conforms to our expectations, the truth of that proposition is confirmed.[8]

Extracting from passages like this one Hempel proposes the Prediction Criterion of Confirmation: If H is a hypothesis, and B is a set of observation sentences, then B confirms H if B can be divided into two mutually exclusive subsets, B_1 and B_2, such that B_1 is not empty and every sentence of B_1 can be logically deduced from B_2 in conjunction with H, but not from B_2 alone. Taking for H the expression "$(x)(P(x) \supset Q(x))$" and supposing that B consists of sentences asserting that some finite set of individuals $a_1, a_2, \ldots a_n$ have the properties "P" and

"Q," we see that the Prediction Criterion states that we may form two subsets B_1 and B_2 such that B_1 contains the observation sentences "Q (a_1)," "$Q(a_2)$,". . . , "$Q(a_n)$" and B_2 contains the sentences "$P(a_1)$," "$P(a_2)$,". . . , "$P(a_n)$." Given these two subsets we would say that B confirms H since every sentence in B_1 is logically implied by B_2 in conjunction with H, but not from B_2 alone. The Prediction Criterion assumes that scientific hypotheses express a conditional connection between properties, such that a prediction in terms of a hypotheses will always be an observation sentence, e.g. "$Q(a_1)$."

Hempel criticizes the Prediction Criterion by noting that it can not be applied to hypotheses which have a more complex form than our example. If we consider the example of the sentence "$(x)(y)R(xy) \supset (Ez)R'(xz))$" (where "R" and "R'" are observable relations), we need only assume an infinite universe of objects to see that no prediction which is an observation sentence can be deductively derived from it. For, if we begin by considering an instance of the sentence, instantiating "x" to "a," we would first have to show that "a" stands in the relation "R" to all objects; but "$(y)R(ay)$" can not be logically implied by any finite set of observation sentences. However, we might view the confirming evidence of "Raa," "Rab" and "Rac" to be sufficient to establish "$(y)R(ay)$" nondeductively: But, with "$(y)R(ay)$" on hand we could only derive "$(Ez)R'(az)$." Consequently, Hempel sees the chain of reasoning which leads from given observations to predictions as involving not only deductive inferences but certain nondeductive steps as well; but these nondeductive steps are made on the basis of confirming evidence and are not deductively valid. In short, Hempel sees the Prediction Criterion as circular since the requirement of "logically implied by" must be replaced, in most important cases, by the requirement of "obtained by a series of steps including nondeductive inferences" and, since the nondeductive steps rely on the concept of confirmation, we are back to the question of explicating confirmation.

After rejecting both Nicod's Criterion and the Prediction Criterion as inadequate explicata, Hempel proceeds with the construction of his explicatum, his logic of confirmation. He begins by setting forth adequacy conditions for any explicata of confirmation. (We will follow Hempel's numbering throughout).

Adequacy Conditions

(8.1) Entailment Condition. Any sentence which is entailed by an observation report is confirmed by it.

(8.2) Consequence Condition. If an observation report confirms every one of a class K of sentences, then it also confirms any sentence which is a logical consequence of K.

(8.21) Special Consequence Condition. If an observation report confirms a hypothesis H, then it also confirms any consequence of H.

(8.22) Equivalence Condition. If an observation report confirms a hypothesis H, then it also confirms every hypothesis which is logically equivalent to H.

With regard to this first group of Conditions, we may note that Hempel, particularly in "A Purely Syntactical Definition of Confirmation," is basing his conception of confirmation on the model of the relation of entailment (if the domain of the relation of entailment is restricted to molecular sentences, then entailment is a subrelation of confirmation). Hempel is characterizing entailment in the usual way, namely as the converse of the syntactical consequence relation, i.e. the converse of the relation ". . . is deducible, by means of a finite number of applications of the rules of inference of first-order predicate calculus without identity, from . . . ." Given this model, it is clear that Conditions 8.21 and 8.22 follow from 8.2. Furthermore, these Conditions stipulate that whatever confirms a given hypothesis also confirms any "weaker" hypothesis. To justify this feature of his confirmation relation Hempel writes:

> . . . any . . . consequence is but an assertion of all or part of the combine content of the original hypothesis and has therefore to be regarded as confirmed by any evidence which confirms the original hypothesis.[9]

Hempel appears to be thinking of cases where one hypothesis makes a weaker claim than another and consequently any evidence which confirms the stronger could not disconfirm the other, since the weaker hypothesis is not claiming anything beyond the stronger hypothesis. However, the nonintuitive aspect of this, otherwise plausible, claim is, as we shall see later, that given a chain of hypotheses each one being a consequence of the one before, the "weakest" hypothesis is confirmed by all the evidence which confirms each "stronger" hypothesis.

(8.3) Consistency Condition. Every logically consistent observation report is logically compatible with the class of all the hypotheses which it confirms.

(8.31) Unless an observation report is self-contradictory, it does not confirm any hypothesis with which it is not logically compatible.

(8.32) Unless an observation report is self-contradictory, it does not confirm any hypotheses which contradict each other.

Hempel hints that perhaps his Consistency Condition is too strong: We might think of a finite set of measurements concerning the changes of one physical magnitude, x, given the changes in another, y. This set of observation sentences may be said to confirm several different hypotheses which designate different mathematical functions in terms of which the relationship between x and y can be expressed. But, since there is at least one value of x for which each function will assign different values of x, these hypotheses are incompatible. Despite this difficulty, Hempel feels that it is important to devise a theory of confirmation which satisfies all of the logical Adequacy Conditions--such a theory would in effect set a limit to the strength of hypotheses which can be confirmed by given evidence.

Hempel offers a final Adequacy Condition, namely the condition of material adequacy. An explicatum of confirmation is materially adequate if it is adequate in our sense, i.e., "it has to provide a reasonably close approximation to that conception of confirmation which is implicit in scientific procedure and methodological discussion."[10]

The final step to the development of the "Satisfaction Criterion" of confirmation which Hempel wishes to propose consists of a technical method for restricting the application of a hypothesis to a set of individuals mentioned in the evidence: The "development of a hypothesis h for a finite set C" is the unquantified string of expressions which states what h would assert if there existed in the universe only the individuals included in the set C. E.g. the development of "$(x)(P(x) \supset Q(x)$" for the set $\{a,b,c\}$ is "$P(a) \supset Q(a)$ & $P(b) \supset Q(b)$ & $P(c) \supset Q(c)$." In "A Purely Syntactical Definition of Confirmation" Hempel proves some simple theorems concerning this notion.[11]

The following definitions form the basis for Hempel's explicatum for the classificatory conception of confirmation:

(9.1) An observation report e directly confirms a hypothesis h if e entails the development of h for the set of those objects which are mentioned in e.

(9.2) An observation report e confirms a hypothesis h if h is entailed by a set of sentences K each of which is directly confirmed by e.

(9.3) An observation report e disconfirms a hypothesis h if it confirms the denial of h.

(9.4) An observation report e is neutral with respect to a hypothesis h if e neither confirms nor disconfirms h.

These definitions form the Satisfaction Criterion of confirmation, i.e., a hypothesis is considered confirmed by a given observation report if the hypothesis is satisfied in the finite set of objects mentioned in the report.

Examples: Given the hypotheses

h_1 $(x)(P(x) \supset Q(x))$
h_2 $(x)(P(x) \supset (Ey)Q(yx))$,

a set of sentences,

K $\{(x)(P(x) \supset R(x)),\ (x)(R(x) \supset (Ey)Q(yx)\}$,

and the observation reports

e_1 $P(a)$ & $Q(a)$ & $\sim P(b)$ & $\sim Q(b)$ & $\sim P(c)$ & $\sim Q(c)$
e_2 $P(a)$ & $R(a)$ & $Q(ba)$ & $P(b)$ & $R(b)$ & $Q(ab)$
e_3 $P(a)$ & $\sim Q(a)$ & $P(b)$ & $\sim Q(b)$
e_4 $P(a)$ & $\sim Q(b)$,

we have that:

(1) e_1 directly confirms h_1, since the development of h_1 for the set $\{a,b,c\}$ namely "$P(a) \supset Q(a)$ & $P(b) \supset Q(b)$ & $P(c) \supset Q(c)$"

is entailed by e_1.

(2) e_2 confirms h_2, since (i) h_2 is a logical consequence of K, (ii) the developments of each element of K for the set $\{a,b\}$ are entailed by e_2.

(3) e_3 disconfirms h_1, since e_3 directly confirms the development of the denial of h_1, namely "$(Ex)(P(x) \& \sim Q(x))$" for the set $\{a,b\}$.

(4) e_4 is neutral with respect to h_1, since e_4 neither confirms nor disconfirms h_1.

Hempel's Satisfaction Criterion is a syntactical explicatum for classificatory confirmation. This explicatum is complete, in the sense that for every observation report and any hypothesis the report either confirms, disconfirms or is neutral with respect to the hypothesis. Furthermore, the Satisfaction Criterion is consistent, in the sense that no consistent observation report confirms and disconfirms the same hypothesis. We may say, as a consequence, that the Satisfaction Criterion is formally adequate. We will consider the adequacy (in our sense) of Hempel's explicatum in Chapter IV when we consider the problem posed by the Paradox of the Ravens. However, our primary concern is not with the classificatory notion of confirmation as such but rather with the related comparative notion.

Our goal is to devise an explicatum of comparative confirmation which is in the spirit of Hempel's classificatory explicatum and which might be offered as a selection criterion for the problem of A-acceptability. Although Hempel hints that the problem of A-acceptability can be approached via a selection criterion based on his confirmation relation, he does not develop this point.[12] Hence, we will refer to the "Confirmatory Framework" in what follows to distinguish what we are about to present from Hempel's purely classificatory theory.

We might begin by considering how the Confirmatory Framework would respond to the first question mentioned in Chapter I, that is, "Which hypothesis should I pick given the evidence which is at hand?" It is reasonable to suppose that the Confirmatory Framework would respond as follows: To determine which hypothesis is better confirmed by the evidence at hand merely compare the number of confirming instances of each hypothesis: If one hypothesis is confirmed by more observation reports than the other hypothesis then the former is more confirmed than the latter. This response, although in the spirit of Hempel's conception of confirmation, is not without its problems. In the first place, it is clear that scientists recognize that some test results are more important than others, and hence that the mere number of confirming instances of a hypothesis cannot be the basis for a rational choice. Secondly, merely repeating the same experiment, and noting the same observation report, would provide more confirming instances for a hypothesis but not, we would like to think, more confirmation. And lastly, if the two rival hypotheses are such that no confirming instance of one is a confirming instance of the other, then there would be no point to comparing the number of confirming instances of each hypothesis.

It is not clear how to remedy these difficulties. However, when the two sets of confirming instances are comparable with regard to the subset relation then the Confirmatory Framework can be thought to be giving the advice that one should pick the hypothesis which is confirmed by the same observation reports as its rival and more besides. In such a case, the problems mentioned above do not arise.

We will view the comparison of hypotheses in terms of the relation of set inclusion obtaining between sets of confirming instances to be central in what follows. It should be noted that this approach does not allow for the possibility of comparing hypotheses whose sets of confirming instances are disjoint, or for the comparing of hypotheses whose sets of comfirming instances are such that one is not included in the other. However, for our concerns this limitation has little effect, and it is sufficient to consider only the case where the sets of confirming instances of rival hypotheses are comparable by the subset relation. Cases like these can be intuitively characterized as cases where what one hypothesis says about the world is included in what another hypothesis says; and logically this situation is described by saying that one hypothesis entails the other. Hence, in what follows we will assume that there is an entailment relation between the two rival hypotheses and it is because of this relation that they can be compared from the standpoint of the Confirmatory Framework.

When the evidence on hand is such that the sets of confirming instances for the two hypotheses are equivalent, which hypothesis would the Confirmatory Framework have to pick? It would be in the spirit of Hempel to suggest that the Confirmatory Framework would have us pick that hypothesis which was more confirmable, the hypothesis which is more likely to accord with future evidence. Hence, the Confirmatory Framework would reply to the second question we have associated with A-acceptability by saying that if preference cannot be established in terms of present evidence then a choice is to be made in terms of which hypothesis has the largest set of possible confirming instances; this hypothesis is the more confirmable of the two and should be A-accepted on that account. It is at this point that the fact that we are extrapolating beyond Hempel becomes evident: Hempel was only concerned to explicate the notion of confirmation as that notion applied to observation reports on hand. However, given the fact that we are here only concerned with hypotheses which are related by entailment, the selection criterion which has been proposed is clearly in accord with Hempel's conception of confirmation.

Our task now is to formally define the two selection criteria which have been informally developed above. Our principal aims are to formally define the relation of "more confirmable than" and to indicate that this selection criterion is weaker-preferring. We begin by characterizing the elements of the sets of possible confirming instances: Definition 2-1. A direct satisfier of a hypothesis is any observation report which directly confirms the hypothesis.

Definition 2-2. A satisfier of a hypothesis is any observation report which directly confirms some set of sentences which entails the hypothesis.

In what follows we will understand "S_n" to be a non-empty set of direct satisfiers and satisfiers. We may begin with some simple theorems about sets of satisfiers. We will employ Hempel's symbolism where

"$Cfd(e_1,h_1)$" reads "e_1 directly confirms h_1" and "$Cf(e_1,h_1)$" reads "e_1 confirms h_1."

Theorem 2-1. If $Cfd(e_1,h_1)$ then $Cf(e_1,h_1)$.

Proof: Since e_1 directly confirms h_1, and since h_1 entails itself, it follows by 9.2 that $Cf(e_1,h_1)$.

Theorem 2-2. Any satisfier of h_1 confirms h_1.

Proof: By Definition 2-2 and 9.2.

Theorem 2-3. If h_1 entails h_2, then if S_1 is the set of satisfiers of h_1, then for any arbitrary e_1 in S_1 $Cf(e_1,h_2)$.

Proof: By Theorem 2-2, Definition 2-1 and Theorem 2-1 it follows that $Cf(e_1, h_1)$. And by 8.31 we have $Cf(e_1,h_2)$.

Theorem 2-4. If h_1 and h_2 are logically equivalent, then, for any e_1 in S_1, $Cf(e_1, h_1)$ if and only if $Cf(e_1,h_2)$.

Proof: The result follows in both directions by Theorems 2-3.

We may now define the Confirmatory Framework's comparative confirmability relation "$CF(h_1,h_2)$" in line with our previous discussion.

Definition 2-3. A hypothesis h_1 is more confirmable than another h_2, i.e., $CF(h_1,h_2)$, if where S_1 is the set of satisfiers of h_1 and S_2 is the set of satisfiers of h_2 we have $S_2 \subset S_1$.

Our Theorem 2-3 is the analogue for possible confirming instances of Hempel's Special Consequence Condition (8.21). On the basis of Theorem 2-3 it can be established, where h_1 entails h_2, and S_1 is the set of satisfiers of h_1 and S_2 is the set of satisfiers of h_2, that $S_1 \subseteq S_2$. We now state and prove a theorem which shows a stronger result and establishes the weaker preferring characteristic of $CF(h_1,h_2)$.

Theorem 2-5. If h_1 entails h_2, but h_2 does not entail h_1, then $CF(h_2,h_1)$ and not $CF(h_1,h_2)$.

Proof: We may assume that h_1 and h_2 are consistent hypotheses. From Theorem 2-3 it would follow that at least, where S_1 is the set of satisfiers of h_1 and S_2 is the set of satisfiers of h_2, we have $S_1 \subseteq S_2$. Since h_2 does not entail h_1, there is a statement E such that h_1 entails E but h_2 does not (E is a consistent statement since h_1 is). It would follow that the statement $h_2 \& \sim E$ is consistent, call it h_3. We consider the development of h_3,

$D(h_3)$, for some set of individuals such that $D(h_3)$ is consistent. (Actually, the domain required here may be infinite, though this will not usually be the case. We could extend 9.1 and 9.2 to cover this possibility by speaking of a set of observation reports instead of a single observation report. This would necessitate changes in Definitions 2-1 and 2-2. For the sake of simplicity we will ignore this possibility.) By 8.21, $Cf(D(h_3),h_2)$, since $Cf(D(h_3),h_3)$ and h_3 entails h_2. And by 8.21 again, since h_3 entails $\sim E$, we have $Cf(D(h_3),\sim E)$, as well. However, it is not the case that $Cf(D(h_3),h_1)$ since that would be in violation of Hempel's Consistency Condition 8.32. Hence, there is an element of S_2, namely $D(h_3)$, which is not an element of S_1, so $S_1 \subset S_2$. So by Definition 2-3 we have $CF(h_2,h_1)$ and, of course, not $CF(h_1, h_2)$.

On the basis of Theorem 2-5, given a "chain" of hypotheses, $h_1,h_2, \ldots, h_n$, such that h_i $(1 < i \leq n)$ is entailed by its predecessor h_{1-i}, it is the case for each h_i that it is more confirmable than every preceding hypothesis h_j $(1 \leq j < i)$. It would not be difficult to show as well that every contradictory sentence is "least confirmable" whereas every tautological sentence is "most confirmable." We will call any theory of comparative confirmability for which it is the case that if h_1 entails h_2 then h_2 is more confirmable than h_1 a theory which is "weaker preferring."

With the selection criterion $CF(h_1,h_2)$ on hand we may now devise for the Confirmatory Framework preference policies for A-acceptability:

Definition 2-4 A hypothesis h_1 is more A-acceptable on the basis of the Confirmatory Framework than another hypothesis h_2 if:

I. Given evidence at hand, the set of confirming instances of h_2 is properly contained in the set of confirming instances of h_1;

II. Given that the sets of confirming instances are equivalent, then $CF(h_1,h_2)$.

Given this definition we may review the responses which the Confirmatory Framework gives to the two questions associated with A-acceptability.

I. Which hypothesis should I pick given the evidence which is at hand?

The Confirmatory Framework responds here that, given the case where the two hypotheses are comparable, when one, h_1, entails the other, h_2, one should pick the weaker hypothesis h_2 since all available evidence which confirms h_1 confirms h_2, and h_2 may be confirmed by more evidence.

II. Which hypothesis should I pick when the evidence at hand supports, equally well, both hypotheses?

To this the Confirmatory Framework replies that, given entailment between h_1 and h_2, one should once again pick the weaker hypothesis h_2, since all possible, future evidence which will confirm h_1 will also confirm h_2, and h_2 will be more confirmable as well.

It should be noted that Definition 2-4 provides a sufficient condition for A-acceptability of hypotheses but not a necessary and sufficient condition. This is in accord with Hempel's original work in the theory of confirmation since he would allow that other selection criteria might be employed in the A-acceptance of hypotheses. This feature of the Confirmatory Framework is in contrast to the next theory of confirmatory logic which we will consider for which the selection criteria for the two questions of A-acceptability are intended to be both necessary and sufficient conditions for A-acceptance.

FOOTNOTES TO CHAPTER II

1. Carl Hempel, "Studies in the Logic of Confirmation," (hereafter Studies), in *Aspects of Scientific Explanation* (New York: Free Press, 1965), pp.3-46.

2. Carl Hempel, "A Purely Syntactical Definition of Confirmation," *Journal of Symbolic Logic*, 8, No.4 (December, 1943), pp.122-43.

3. Hempel, Studies, p.10.

4. Hempel, Studies, p.10; quoted from J. Nicod, *Foundations of Geometry and Induction*, translated by P.P. Wiener (London, 1930), p.219.

5. Hempel, Studies, p.12.

6. I. Scheffler, *The Anatomy of Inquiry* (New York: Knopf, 1963), p.246.

7. Hempel, Studies, pp.13-14.

8. A.J. Ayer, *Language, Truth and Logic* (London, 1936), pp.142-3.

9. Hempel, Studies, p.31.

10. Hempel, Studies, p.34.

11. Among the theorems Hempel uses are the following:
(i) for any finite set of individuals, and the developments C_1 and C_2 for hypotheses h_1 and h_2 if h_1 implies h_2 then C_1 implies C_2;
(ii) if, for two hypotheses h_1, h_2, h_1 is equivalent to h_2, then the developments C_1 and C_2, for any finite set of individuals, are equivalent;
(iii) for every finite set of individuals, the development of a contradictory (analytic) hypothesis is contradictory (analytic).

12. Hempel, Studies, pp.9-10.

CHAPTER III

KARL POPPER AND CORROBORABILITY

We will present in this chapter Karl Popper's explicatum of the quantitative confirmation relation "the degree to which a statement x is confirmed (corroborated, supported) by a statement y is r". For the most part this explicatum is set out in Appendix *ix of Popper's The Logic of Scientific Discovery[1]. In order to appreciate why Popper has chosen to view the corroboration functor "$C(h_1,e_1,b)$" in the manner he has, we must first explain some of the informal notions which together form the basis of Popper's conception of the "aim of science".

Whereas the common conception of the methodology of science acknowledges induction, Popper's conception is purely deductive. Popper refuses to accept the logical validity (or the epistemological value) of nondemonstrative inference. In place of the activity of inductively inferring from particular statements (evidence) to general assertions (hypotheses), Popper inserts the activity of critically examining general assertions in the hope of falsifying them by particular statements (test results). On the basis of Popper's work toward a "theory of demarcation"--a theory which hopes to distinguish between genuine, scientific hypotheses and "pseudo-hypotheses"--he has decided that the essential attribute of scientific hypotheses is that they are falsifiable.

In Popper's terminology, a hypothesis is falsifiable when and only when it is testable (or refutable). Hence with regard to scientific hypotheses Popper writes:

> I shall require that its logical form shall be such that it can be singled out, by means of empirical tests, in a negative sense: it must be possible for an empirical scientific system to be refuted by experience.[2]

Given the logical manoeuvre implied by this quote, the falsifiability of hypotheses is contingent upon two requirements: First, hypotheses must be universal statements--that is, statements which are symbolized into universally quantified expressions.[3] Second, statements which may falsify a hypothesis ("potential falsifiers") must be certain "basic statements" which are "forbidden" or "ruled out" by the hypothesis.[4] The first requirement can be seen as Popper's rejection of the "General Applicability Condition" which was mentioned in Chapter II. As for the second requirement, Popper writes that basic statements must satisfy two conditions: (i) no basic statement can be derived from a universal statement alone; and (ii) a basic statement can contradict a universal statement. Popper insists that basic statements must be able to play the role of test statements (i.e. reports of the outcomes of possible experiments), and in this role they must be singular statements of observable events.

By condition (i) the expression "$P(a) \supset Q(a)$" can not be a basic statement inasmuch as it can be derived from the universal statement "$(x)(P(x) \supset Q(x))$". However, by condition (ii) the negation of this expression, namely "$P(a) \;\&\; {\sim}Q(a)$", is a basic statement; furthermore it is a potential falsifier of "$(x)(P(x) \supset Q(x))$". However, the fact that "$P(a) \;\&\; {\sim}Q(a)$" is a basic statement by condition (ii) runs counter to condition (i) inasmuch as "$P(a) \;\&\; {\sim}Q(a)$" can be derived from a universal statement, namely "$(x)(P(x) \;\&\; {\sim}Q(x))$". There is some evidence to indicate that Popper intends condition (i) to read "No basic statement *of a hypothesis* h_1 can be derived *from* h_1."[5] Put in this way, "$P(a) \;\&\; {\sim}Q(a)$" becomes a basic statement of "$(x)(P(x) \supset Q(x))$" although not of "$(x)(P(x) \;\&\; {\sim}Q(x))$". This way of putting condition (i) has the virtue that it reinforces Popper's desire that basic statements of hypotheses must be able to function as potential falsifiers of hypotheses. Unfortunately, however, in terms of the new condition (i) there is no difference between a potential falsifier and a basic statement.

Further difficulties with Popper's notion of a basic statement arise in connection with his policy to exclude negations of basic statements from the set of basic statements.[6] As Popper explains this restriction, if we disallow negations of basic statements then we can exclude as well all disjunctions and conditionals from the set of basic statements. However, if we agree that, for some hypothesis, "P(a) &~Q(a)" is a legitimate basic statement, then there is no reason to suppose that "~Q(a)" isn't also a basic statement since it meets both conditions with respect to the hypothesis "(x)Q(x)".

In view of these difficulties, and in order to make sense of the material to follow, we will assume that Popper's characterization of "basic statement" is mistaken. We will suppose in what follows that a basic statement is just an observation report (in Hempel's sense) and that a potential falsifier is just an observation report which entails the negation of a universal statement. We may retain Popper's requirement that a potential falsifier can be a report of the outcome of a test, and furthermore that a falsifier (i.e. a counter-instance to a hypothesis) must be a report of the outcome of tests.

A hypothesis is called "falsifiable" if the set of its potential falsifiers is not empty. Furthermore, hypotheses may be more, or less, easily falsifiable. To Popper's mind it is incumbent upon the scientist to seek out hypotheses which are more easily falsifiable, for the hypothesis which has a greater variety and number of potential falsifiers is, in effect, more restrictive in the range of events which it "permits". Consequently, hypotheses should be judged with regard to their "universality"--their range of applicability--as well as their "precision"--their ability to predicate specifically. Both of these notions go to make up the important concept of "empirical content". The empirical content of a hypothesis is the empirical information conveyed by the hypothesis. The amount, or extent, of empirical content of a hypothesis is measurable by the "degree of testability" of that hypothesis.

The natural move at this point is to ascertain how the degree of testability of any hypothesis is to be evaluated. Popper notes that we may be able to compare hypotheses with regard to their degrees of testability by comparing sets of potential falsifiers (by means of the subset relation). This being unsatisfactory, because the sets of potential falsifiers are usually infinite, Popper suggests two more techniques before setting up a means for calculating degree of testability. The first technique involves a comparison between the numerical value which can be associated with the "dimension" of hypotheses. The dimension of a hypothesis is determined by the smallest number of conjuncts required for a basic statement such that it be capable of falsifying the hypothesis. Closely associated with the dimension of a hypothesis is its "simplicity" which Popper takes to be based on the number of freely adjusted parameters in the hypothesis. Both of these notions do not provide as sensitive a criterion for comparing hypotheses as Popper feels is possible. Out of these discussions Popper extracts the idea that testability must just be the same as improbability. Popper finds this identification of testability (and thus extent of empirical content) and improbability to be the touchstone of his conception of corroboration; thus "the more a statement asserts, the less probable it is," and "aiming at high probability entails a counter-intuitive rule favoring ad hoc hypotheses."[7] Popper's choice of a corroboration functor is based on this notion.

Although the calculus of probability which Popper develops (see below) is formal, in the sense that it does not assume any particular interpretation,[8] Popper always assumes the logical interpretation of the calculus. In terms of the logical interpretation of probability the probability of a hypothesis h_1, "$p(h_1)$", is understood to be the initial or a priori probability of h_1, the value of which ranges 0 to 1 where $p(h_1)=0$ when h_1 is self-contradictory and $p(h_2)=1$ when h_2 is analytic. Furthermore, the relative or conditional probability of a hypothesis h_1 given another statement e_1--i.e. "$p(h_1,e_1)$"--also ranges in value from 0 to 1 where $p(h_1,e_1)=0$ when e_1 contradicts h_1 and $p(h_2,e_2)=1$ when h_2 is entailed by e_2. Clearly then if h_1 is self-contradictory then $p(h_1,e_1)=0$ (for any e_1 whatsoever) and if h_2 is analytic then $p(h_2,e_2)=1$ (for any e_2 whatsoever).

Popper views the empirical content of a hypothesis h_1 to be $1-p(h_1)$, and the relative empirical content of h_1 given e_1 to be $1-p(h_1,e_1)$.[9] Popper is more interested in the beginning to clarify the general notion of initial empirical content, "$C(x)$", where "x" may be any statement at all. To support the claim that initial empirical content is measured as the complement of probability, Popper argues, with regard to hypotheses, thusly:[10] The scientist's most important task is to strive for hypotheses which adequately describe the world. Toward this end he must eliminate all hypotheses which are logically possible but false; since there is only one true description of the world the scientist will have better luck eliminating one by one the infinitely many logically possible alternative hypotheses. But, by adopting this critical approach the scientist is not interested in hypotheses which have a high initial probability, rather he is seeking hypotheses which are more easily eliminable. But these are just the hypotheses which risk the most, those which have the most content, those for which refutation is more probable. If the scientist was concerned with high probability he would advance hypotheses which would say little (since tautologies which have the highest initial probability say nothing). Hence, the more a hypotheses says about the world the less probable it is and the greater its empirical content.

The preceding argument--which we may call the Improbability Argument--is central to Popper's thinking with regard to corroboration. The Improbability Argument suggests that there is a quantitative means for comparing hypotheses with regard to their degree of testability (= empirical content), namely one which is determined by probability values. However, there are problems associated with evaluating expressions like "$p(h_1)$" and "$p(h_1,e_1)$". These problems are caused by the fact that Popper characterizes hypotheses as "unrestricted universals" (statements which claim to be true for any place and any time for infinite universes of discourse[11]).

In the first place, Popper maintains that the initial probabilities of all unrestricted universals are the same, just zero.[12] Secondly, it is generally agreed that for all unrestricted universals the value of the relative probability given any evidence is also zero (we will omit the proof of this assertion[13]). Popper's claim follows from the commonly used definition of initial probability:

$p(h_1)=p(h_1,t)$, where "t" is any tautology.

Hence, if h_1 is an unrestricted universal and therefore $p(h_1,e_1)=0$ for any e_1 whatsoever, then clearly $p(h_1,t)=p(h_1)=0$. Popper proposes several other more direct proofs to support his contention concerning the zero initial probability of unrestricted universals,[14] but we will omit these proofs and pass on to the solution to this difficulty which Popper offers.

Popper wishes to hold that if, for any statements a_1 and a_2, it is the case that $p(a_1) < p(a_2)$ then it follows that $C(a_2) < C(a_1)$; however, he also wishes to hold that when a_1 and a_2 are unrestricted universals (i.e. when they are hypotheses) it is the case that $p(a_1) = C(a_2) = 1)$. He concludes therefore that the differences in the contents of hypotheses can not be completely expressed by probabilities.[15] Still, this "does not mean that we cannot express the difference in content between a_1 and a_2 in terms of probability."[16] For if a_1 entails a_2 (but not vice versa) it follows that $p(a_1,a_2) < 1$ while $p(a_2,a_1)=1$, although, at the same time $p(a_1)=p(a_2)=0$. Hence, we should have $p(a_1,a_2) < p(a_2,a_1)$. Consequently, measurements based on probabilities are "too coarse, and insensitive to the differences"[16] between hypotheses with regard to their content. To remedy this Popper introduces the notion of the "fine structures" of content and probability. In terms of the fine structures of probability and content we may distinguish between those cases where we intuitively would like to say that the content of one statement is less than the content of another although mathematically the contents are equal. As for the problem of determining that intuitively $C(a_1) < C(a_2)$ even though mathematically $C(a_1)=C(a_2)$, i.e. cases where two unrestricted universals have intuitively different contents, Popper proposes the following rule: If for "sufficiently large" but finite universes we have $C(a_1) < C(a_2)$ (i.e. it can be shown that $p(a_2) < p(a_1)$) then we infer that this is the case for an infinite universe as well, although mathematically for an infinite universe it is the case that $C(a_1) = C(a_2) = 0$.[17]

The fine structure value of $C(h_1)$ where "h_1" is a hypothesis, can also be based upon the dimension of h_1, which is in turn calculated by the number of parameters found in h_1. Popper has argued elsewhere that for sufficiently large universes (although not for infinite universes) if h_1 has fewer parameters than h_2 then $p(h_1) < p(h_2)$.[18] This stirs up another difficulty however: How may we determine the fine structure value of $C(e_1)$ where "e_1" is evidental in Popper's sense, i.e. a set of basic statements? This value surely can not be calculated in terms of the number of parameters in e_1 since, owing to the formal character of basic statements, the number of parameters of any conjunction of basic statements will be the same, namely zero. Popper does mention that there are techniques for calculating the value of $p(e_1)$ (and hence $C(e_1)$ as well) when e_1 is a statistical report about a certain finite sample.[19] Otherwise, there is no technique for determining the fine structure values of either $p(e_1)$ or $C(e_1)$.

As we will argue later this inability to provide values for certain key probability expressions has dire effects on Popper's selection criteria. Occasionally Popper notes this difficulty and attributes the impossibility of calculating the value of $p(e_1)$ to the fact that there can not be a satisfactory metric of logical probability.[20] Still, Popper is convinced that the virtue of his explicit correlation of corroborability and improbability is such that difficulties with calculating the values of probability expressions are of little importance.

In order to present the definitions of Popper's various corroborability relations it is necessary at this point to introduce a calculus of probability; and it is appropriate that we should introduce Popper's own calculus, the system S.[21] The principal distinction of Popper's system S is that it allows for the meaningfulness of relative probability statements even when the second argument has an initial probability of zero. (Popper refers to this feature of probability calculi as "symmetry"--if "$p(a,b)=r$" is well-formed then so is "$p(b,a)=s$".) In most axiom systems relative probability is defined by means of the Multiplication Axiom such that $p(a,b)=p(ab)/p(b)$, and hence "$p(a,b)$" is well-formed only if $p(b) \neq 0$. Popper's system S introduces as a primitive the expression "$p(a,b)$" thus avoiding the need of prefixing every theorem about relative probability by the statement that the initial probability of the second argument is not equal to zero. System S consists of a set S (the universe of discourse) whose elements are "a", "b", "c",... and two other undefined notions, namely the operations "ab" (the product of a and b) and "-a" (the complement of a). The axioms and postulates of S are:

Postulate 1. The number of elements of S is at most denumerably infinite.

Postulate 2. If a and b are in S, then $p(a,b)$ is a real number, and the following axioms hold:

A1 $(Ec)\ (Ed)\ p(a,b) \neq p(c,d)$,

A2 $((c)(p(a,c)=p(b,c)) \supset p(d,a)=p(d,b)$,

A3 $p(a,a)=p(b,b)$

Postulate 3. If a and b are in S, then ab is in S; and if c is in S (and so bc as well) then the following axioms hold:

B1 $p(ab,c) \leq p(a,c)$,

B2 $p(ab,c)=p(a,bc)p(b,c)$.

Postulate 4. If a is in S, then -a is in S; and if b is in S then the following axiom holds:

C $p(b,b) \neq p(c,b) \supset p(b,b)=p(a,b)+p(-a,b)$.

Postulate AP. If a and b are in S, and if $p(b,c) \geq p(c,b)$ for every c in S, then $p(a)=p(a,b)$.

Axiom A2 provides for the "symmetry" of system S: By A2 we can extend the probabilistic equivalence of a and b to the second argument place even in cases where $p(a)=p(b)=0$. The question still remains, however, how we may calculate the value of "$p(a,b)$" when "b" is an unrestricted universal. This is an important difficulty here inasmuch as both the qualitative corroboration relation "$Co(x,y)$" and the quantitative functor "$C(h_1,e_1,b)$" depend, as we will see, on the value of "$p(y,x)$" (which Popper reads as "the likelihood of x given y"). S does not help to evaluate expressions like "$p(e_1,h_1)$" for although it allows that "$p(e_1,h_1)$" is meaningful when $p(h_1)=0$ it does not provide a means for calculating the value of the expression. We may suppose that Popper intends the fine structure values of probability statements to be used in all cases. At bottom, however, Popper seems content to leave the problem of evaluating probability expressions unanswered.

Popper discusses the qualitative relation of corroboration, "$Co(x,y)$", in only one short passage of Appendix *ix.[22] Working on the assumption that evidence y corroborates (confirms or supports) a statement x if, and only if y increases the probability of x, Popper first suggests that $Co(x,y)$ if and only if $p(x,y) > p(x)$. However, noting that it is a theorem of the calculus of probability that if $p(x) \neq 0$ and $p(y) \neq 0$ then $p(x,y) > p(x)$ if and only if $p(y,x) > p(y)$, Popper decides on the following criterion:

(1) $Co(x,y)$ if and only if $p(y,x) > p(y)$.

(1) is inadequate for the case of $Co(h_1,e_1)$, for it fails to capture an important feature of evidence; i.e. e_1 must be "a report of the severest tests we have been able to design."[23] This feature of evidence, which may be seen to be a consequence of the Improbability Argument, motivates Popper's immediate abandonment of the qualitative relation in favor of the quantitative functor. It has been amply demonstrated, by R.H. Vincent,[24] that (1) is indeed wholly unsatisfactory if we drop the condition that "y" represents the results of severe tests of the hypothesis "x".

To develop the quantitative notion of corroboration Popper feels it necessary to devise a means for measuring the severity of tests of a hypothesis. Preliminary to this Popper introduces the notion of "background knowledge" which is a set of statements which includes "all those things which we accept (tentatively) as unproblematic while we are testing the theory."[25] The background knowledge of a hypothesis (which we will be symbolizing by "b" henceforth) forms an integral part of the corroboration functor "$C(h_1,e_1,b)$" (which reads "the degree of corroboration of h_1 by e_1 given, or in the presence of, b"). This functor is developed in terms of the severity functor "$S(e_1,h_1,b)$" and it is to this that we now turn.

If we suppose that the evidence e_1 (the set of reports of tests) is a logical consequence of hypothesis h_1 together with the background knowledge b, i.e., $p(e_1,h_1b)=1$, then we may say that the severity of the tests represented by e_1 will be greater the less probable is e_1 given b alone. Popper proposes that we understand the severity of e_1 given b, "$S(e_1,b)$", to be patterned after the measure of empirical content of a statement x, $C(x)$, such that $S(e_1,b)=1-p(e_1,b)$. Although Popper feels that this would do, we may "normalize" $S(e_1 b)$ by the factor $1/1+p(e_1,b)$, giving rise to the following:

(2) $S(e_1,b)=(1-p(e_1,b))/(1+p(e_1,b))$.

Definition (2), which is based on the assumption that $p(e_1,h_1 b)=1$, can be generalized thusly:

(3) $S(e_1,h_1,b)=(p(e_1,h_1 b)-p(e_1,b))/(p(e_1,h_1 b)+p(e_1,b))$. The left-hand side of (3) may now be read "the degree of the severity of test(s) e_1 of h_1, given b", or, alternatively as "the degree of evidential support e_1 of h_1, given b". Arguing that the degree of evidential support given h_1 by e_1 is just h_1's explanatory power with respect to e_1, Popper produces another functor "$E(h_1,e_1,b)$" (which is to read "the degree of explanatory power of h_1 with respect to e_1, given b") such that:

(4) $S(e_1,h_1,b)=E(h_1,e_1,b)$.

We can see from (3) that the "severest test" (the crucial experiment in other words) would be one which was a logical consequence of the hypothesis and background knowledge (so that $p(e_1,h_1 b)=1$) while being at the same time highly improbable with respect to the background knowledge alone (so that $p(e_1,b)$ approaches zero). By (4) we can say that a hypothesis has a greater degree of explanatory power with respect to some evidence as the value of $E(h_1,e_1,b)$ approaches one. Conversely, if the evidence was a logical consequence of the background knowledge, then the value of the explanatory power functor would be zero. So, our choice of hypothesis can be governed to a certain respect by the explanatory power functor: We must choose the hypothesis which "goes beyond" the background knowledge we have so that reports of tests are not consequences of the background knowledge alone.

Popper now defines the corroboration functor "$C(h_1,e_1,b)$" in terms of "$E(h_1,e_1,b)$" thusly:

(5) $C(h_1,e_1,b)=E(h_1,e_1,b)(1 + p(h_1,b)p(h_1,e_1 b))$.

Another definition can also be given (Popper does not express a preference between the two formulations):

(6) $C(h_1,e_1,b)=p(e_1,h_1b)-p(e_1,b)/p(e_1,h_1b)-p(h_1e_1,b)+p(e_1,b)$.

The value of (5) is that, in view of the preceeding discussion, when $E(h_1,e_1,b)$ approaches one the value of $C(h_1,e_1b)$ approaches that of $1+p(h_1,b)p(h_1,e_1b)$ which in turn approaches one when the value of $p(h_1,b)$ (as well as the value of $p(h_1,e_1b)$) approaches zero. From (6) we can isolate the expression "$p(e_1,h_1b)-p(e_1,b)$" (which is a remnant of the qualitative relation) which ranges from one (for precisely the same reasons as "$E(h_1,e_1,b)$" has its upper bound at one) to negative one (when e_1 entails the negation of h_1 and b entails e_1). From (5) again we see that when $p(h_1,b)$ approaches zero (when, in Popper's terminology, h_1 has a high empirical content with respect to b) then $C(h_1,e_1,b)$ approaches $E(h_1,e_1,b)$ and hence for any evidence the value of $C(h_1,e_1,b)$ increases with the explanatory power of h_1, i.e. with the severity of e_1.

We are now in a position to fit Popper's functor "$C(h_1,e_1,b)$" into the framework of the problem of A-acceptability. To do this we must devise a comparative corroboration relation based on Popper's quantitative notion. Our principal concern will be to isolate the factors in the definition of "$C(h_1,e_1,b)$" which are central to Popper's responses to the two questions of A-acceptability, selection on the basis of present evidence, and selection when present evidence leaves the question of choice undecidable.

In order to avoid cases where hypotheses, evidence, and background knowledge are all independent of each other, we first introduce the familiar notion of stochastic independence:

Definition 3-1 Statement a is stochastically independent of another, b, (written "$SI(a,b)$") if and only if $p(b)=0$ or $p(a)=p(a,b)$.

(It can be shown that a is stochastically independent of b if and only if b is stochastically independent of a.) If for two hypotheses h_1 and h_2 it were the case that $SI(h_1,e_1)$, $SI(e_1,b)$ and $SI(h_2,e_1)$ then it would follow (given the standard theorem that if a and b are independent then $p(ab)=p(a)p(b)$) that $E(h_1,e_1,b)$ and $E(h_2,e_1,b)$ would both have the value zero, and consequently (using definition (5)) $C(h_1,e_1,b)$ and $C(h_2,e_1,b)$ would also have the value zero. By requiring here that the hypotheses, the evidence, and the background knowledge not be independent of one another we are eliminating those trivial sorts of cases (which, we might suppose, never occur in real situations) where the initial probability of the evidence, background knowledge or hypotheses is zero. In this way we are also ensuring that the two hypotheses we are comparing with regard to their corroborability are "affected" by the evidence and the background knowledge.

The comparative corroborability we will now offer comes by way of the comment we made in Chapter I: Given a quantitative measure of corroboration, complete with a metric, the comparative relation can be formed simply and directly by comparing the values of two expressions "$C(h_1,e_1,b)$" and "$C(h_2,e_1,b)$". Therefore:

Definition 3-2 If it is not the case that $(SI(h_1,e_1) \vee SI(e_1,b) \vee SI(h_2,e_1))$, then h_1 is better corroborated by e_1, with respect to b, than is h_2, i.e. $CP(h_1,h_2,e_1,b)$, if and only if $C(h_1,e_1,b) > C(h_2,e_1,b)$.

Unfortunately, given the complexity of the definitions of the corroboration functor, Definition 3-2 is not very illuminating. Furthermore, Definition 3-2 does not enable us to easily determine which preference policies Popper would have scientists follow given the two different decision situations of A-acceptability. Consequently, we must determine which factors involved in the corroborability functors are to come to play given a choice made on present evidence and one made when present evidence does not decide the matter. The means by which we may isolate these factors is simply that of determining under what conditions the degree of corroboration of one hypothesis is greater than the degree of another.

To simplify matters we can begin by noting that the relative probability of e_1 given b is not at issue when we are comparing two hypotheses, and hence this value can be represented by a constant.

So, we will let $p(e_1,b)=s$, where $0<s<1$ (we choose this range so as to conform to the Popperian idea that the evidence must be "risky", that is not directly entailed by the background knowledge). We now isolate the factors which are involved in the definitions of "$E(h_1,e_1,b)$" and "$C(h_1,e_1,b)$" (we will distinguish the two proposed definitions of "$C(h_1,e_1,b)$" by referring to their numbers in this paper, "(5)" and "(6)"). We are here adopting a technique employed by H.E. Kyburg.[26]

Functor	A	B	C
$E(h_1,e_1,b)$	$p(e_1,h_1b)-s$	1	$\frac{1}{p(e_1,h_1b)+s}$
(5) $C(h_1,e_1,b)$	$p(e_1,h_1\ b)-s$	$1+p(h_1,b)p(h_1,e_1b)$	$\frac{1}{p(e_1,h_1b)+s}$
(6) $C(h_1,e_1,b)$	$p(e_1,h_1b)-s$	$\frac{1}{p(-h_1,b)}$	$\frac{1}{p(e_1,h_1b)+s}$

The definitions of each functor can be obtained by multiplying the factors listed under the three columns. The factor which is given in each case under column A, namely $p(e_1,h_1b)-s$, is, according to Popper, "crucial for the functions $E(h,e)$ and $C(h,e)$."[27] Indeed, as Popper goes on to say, the functors "$E(h_1,e_1,b)$" and "$C(h_1,e_1,b)$" are but two different ways of "normalizing" this factor. For Popper $p(e_1,h_1b)-s$ indicates that in order to find a good test-statement e_1, i.e. one which if true would be highly favorable to, and hence a strong corroboration of, h_1 we must find an e_1 which (i) makes $p(e_1,h_1b)$ nearly equal to 1 and (ii) makes $p(e_1,b)$, our value s, nearly equal to 0. Clearly then, one of the conditions which would allow us to say that $CP(h_1,h_2,e_1,b)$ would be that $p(e_1,h_1b)>p(e_1,h_2b)$, which is to say that hypothesis h_1 if true makes e_1 more likely than hypothesis h_2, if true, does.

Taking Popper at his word, we may think of columns B and C as representing different "normalizing" factors of $p(e_1,h_1,b)-s$. The two factors under column B both increase monotonically with the value of $p(h_1,b)$. This last expression is crucial to Popper's approach to the notion of corroboration and constitutes the basis for the determination of what we will call the "relative content of h_1", namely $1-p(h_1,b)$.

Although Popper nowhere considers the question of how this relative content "$C(h_1,b)$" of hypothesis h_1 relates to the (initial) content "$C(h_1)$", we may suppose that it increases monotonically with respect to the initial content. It can be clearly seen that as the relative content of a hypothesis approaches the value one (i.e. as $p(h_1,b)$ approaches zero), the values of both of the factors listed under column B also approach one.

The factor listed under column C is the reciprocal of the expression "$p(e_1,h_1b) + p(e_1,b)$" which is a factor which increases with the value of $p(e_1,b)$, that is s. By holding $p(e_1,b)$ constant as we are, we can focus attention on the two expressions "$p(e_1,h_1b)$" and "$p(e_1,h_2b)$". Once again, if it can be shown that $p(e_1,h_1b) > p(e_1,h_2b)$, then this fact contributes to the result that $CP(h_1,h_2,e_1b)$.

In summary then, if we let $p(e_1,b)=s$ then there are two conditions which determine when one hypothesis is better corroborated than another:

I. The likelihood of the evidence (i.e. the test statements) given the hypothesis. Here it is the value of $p(e_1,h_1b)-s$ which is crucial, and we may call this factor the "severity factor".

II. The relative content of the hypothesis, i.e., the value of $1-p(h_1,b)$.

It is important to note that the evidence statement e_1 used in the severity factor is intended by Popper to be a statement of a test which the hypothesis h_1 has passed and which had been designed to be a sincere attempt to refute h_1. The value of the severity factor can be viewed as the degree to which h_1 has been severely tested, and consequently when it is the case that $p(e_1,h_1b) > p(e_1,h_2b)$ then we should say that hypothesis h_1 has been more severely tested than hypothesis h_2, and having passed the tests is a better tested hypothesis. More generally, if one hypothesis has passed tests which were relatively unlikely given the background knowledge (but very likely given both the hypothesis and the background knowledge), then the hypothesis is well tested. And, if the tests passed by one hypothesis h_1 were more severe relative to the background knowledge then the tests passed by another hypothesis h_2, then h_1 is better tested than h_2.

The severity factor is Popper's selection criterion which determines the preference policy for the question of A-acceptability involving evidence at hand. This Popper has made clear in a recent article where he distinguishes between "pragmatic preference" and "theoretical preference".[28] Here Popper states that on the basis of the evidence gathered so far (and on the assumption that the rival hypotheses have both been viewed from a critical perspective) the scientist should pick the best tested hypothesis, in precisely the sense of "best tested" which we have developed here. Popper views his preference policy, for the case of pragmatic preference, to reflect the proper concern of the critical scientist, namely that the hypothesis which has withstood the severest tests to date is the hypothesis which so far has "proven its mettle" to survive.

The question of theoretical preference comes up when both hypotheses have proven their mettle and have both withstood the same tests, or equally severe tests. When this occurs, and the scientist wishes to make a decision which hypothesis to A-accept, Popper institutes another preference policy, one which is determined by a comparison of the relative contents of the hypotheses. Hence, Popper's response to our second question associated with A-acceptability is this: When both hypotheses have managed to survive the same, or equally severe, tests, then one should pick the hypothesis which relative to the background knowledge is more improbable, i.e., has a higher degree of relative content. It should be noted that like the Confirmatory Framework's confirmability selection criteria, Popper's criteria based upon relative content is *a priori* and makes no reference to actual evidence or test results. We may define Popper's comparative corroborability relation thusly:

Definition 3-3 A hypothesis h_1 is more corroborable than another h_2 (which may be symbolized by $CP(h_1,h_2)$), if and only if, given that neither hypothesis has been refuted, the relative content of h_1 is strictly greater than the relative content of h_2.

It might be simpler to formulate Definition 3-3 in terms of the initial content of the two hypotheses rather than the relative content, thus eliminating the need for a reference to the background knowledge. However, Popper has made it plain that background knowledge must be taken into account when the problem of deciding between hypotheses is involved. Since Popper characterized the background knowledge as a set of statements which includes "old evidence, and old and new initial conditions" as well as "accepted theories"[29] it would not be in the spirit of the Improbability Argument to formulate Definition 3-3 without reference to background knowledge.

To insure that the Confirmatory Framework and Popper's theory of corroborability are comparable with regard to both questions of A-acceptability, we will again consider only the case where the rival hypotheses concerned are such that one entails the other. With this stipulation it is possible to show that Popper's selection criteria are stronger preferring. As far as the severity factor is concerned it is clear that if one hypothesis h_1 entails another h_2 then whatever test which h_2 has passed has been a test of, and has been passed by h_1. Moreover, since h_1 is stronger, and in the intuitive sense says more than h_2, it is very possible that h_1 has passed tests which h_2 has not. This is sufficient to establish that the severity factor generates a stronger preferring preference policy.

With regard to the relative content factor we find a Popperian like J.W.N. Watkins arguing as follows:[30] If one hypothesis h_1 entails another h_2 then (i) whatever evidence which might falsify h_2 would also falsify h_1, and (ii) whatever evidence which might falsify h_1 may or may not falsify h_2, and hence the content of h_1 is at least as great as the content of h_2. This may be shown in terms of probability expressions as well. If h_1 entails h_2 then $p(h_2,h_1)=1$. With regard to the value of $p(h_2)$, we note that there are two "events" possible, namely the case where h_1 is true and when it is false. Hence, $p(h_2)=p(h_1)p(h_2,h_1)+p(\sim h_1)p(h_2,\sim h_1)$. But since $p(h_2,h_1)=1$, we have $p(h_2)=p(h_1)+p(\sim h_1)p(h_2,\sim h_1)$. Since $p(\sim h_1)p(h_2,\sim h_1)\geq 0$, it follows that $p(h_2)\geq p(h_1)$ and hence that $C(h_1)\geq C(h_2)$. Since the initial content of h_1 is greater than or equal to the initial content of h_2, the relative contents of the two hypotheses will be related in the same way. Hence, the relative content factor also generates a stronger preferring preference policy.

From these discussions, and our definition of $CP(h_1,h_2)$, we may give the following definition of A-acceptability on the basis of Popper's theory of corroborability:

Definition 3-4 A hypothesis h_1 is more A-acceptable on the basis of Popper's theory of corroboration if and only if:

I. Given evidence at hand h_1 is better tested than h_2;

II. Given that h_1 and h_2 are equally well tested, then $CP(h_1,h_2)$.

Definition 3-4 is constructed so as to indicate that the two preference policies given by Popper are necessary and sufficient for A-acceptability. This Popper wishes to hold since in several places[31] he insists that his notion of corroborability is the same as that of acceptability. And that Popper seems to mean by "acceptability" what we have called A-acceptability is clear from his comments and examples, e.g.:

> We choose the theory which best holds its own in competition with other theories; the one which, by natural selection, proves itself the fittest to survive.[32]

The hypothesis which proves itself the fittest to survive is, ultimately in Popper's view, that hypothesis which has the greatest content without being refuted.[33] This is the nature of theoretical preference, that preference policy given by part II of Definition 3-4. Popper favors this preference policy, thinking it central to the methodology of science for reasons which we will uncover in Chapter V. For the moment we may review the responses which Popper gives to the two questions associated with A-acceptability.

I. Which hypothesis should I pick given the evidence which is at hand?

This "pragmatic" choice is governed by the severity factor, and, given the case where hypothesis h_1 entails hypothesis h_2, one should pick the stronger h_1 since it has passed all the severe tests h_2 has and perhaps more besides.

II. Which hypothesis should I pick when the evidence at hand supports, equally well, both hypotheses?

Here we must resort to the "theoretical" choice which is governed by the relative contents of the hypotheses. When hypothesis h_1 entails hypothesis h_2 the theoretical choice is a clear one: Hypothesis h_1 will always be at least as improbable relative to the background knowledge as h_2 is, and h_1 may be more improbable than h_2. Hence, since the theoretical preference of hypotheses is governed by their improbability relative to the background knowledge, hypothesis h_1 will always be at least as A-acceptable as hypothesis h_2.

With the preference policies of both the Confirmatory Framework and of Popper now laid out we will begin our critical examination of both approaches. In the next chapter we will concern ourselves with the problem posed by the "Paradox of the Ravens".

FOOTNOTES TO CHAPTER III

1. Karl Popper, *The Logic of Scientific Discovery* (New York: Harper and Row, 1968).

2. Popper, *The Logic of Scientific Discovery*, p.41.

3. Popper, *The Logic of Scientific Discovery*, see Section 15.

4. Popper, *The Logic of Scientific Discovery*, p.69.

5. Popper, *The Logic of Scientific Discovery*, p.101, fn.*1.

6. Karl Popper, *Conjectures and Refutation: The Growth of Scientific Knowledge* (New York: Harper and Row, 1965).

7. Popper, *Conjectures and Refutation: The Growth of Scientific Knowledge*, p.287.

8. Popper, *The Logic of Scientific Discovery*, p.326.

9. Popper, *The Logic of Scientific Discovery*, p.270,

10. See especially, Popper, *The Logic of Scientific Discovery*, p.61 fn *1, pp.113, 118-9, 269-72, 276-81; and Popper, *Conjectures and Refutation: The Growth of Scientific Knowledge*, pp.286-7 and p.217.

11. Popper, *The Logic of Scientific Discovery*, p.62.

12. Popper, *The Logic of Scientific Discovery*, Appendix *vii "Zero Probability and the Fine-Structure of Probability and of Content," especially p.363.

13. See Rudolf Carnap, *Logical Foundations of Probability* (Chicago: University of Chicago Press, 1962), pp.570-71.

14. Popper, *The Logic of Scientific Discovery*, Appendices *vii and *viii.

15. Popper, *The Logic of Scientific Discovery*, p.374.

16. Popper, *The Logic of Scientific Discovery*, p.375.

17. Popper, *The Logic of Scientific Discovery*, p.376.

18. Popper, *The Logic of Scientific Discovery*, p.381.

19. Popper, *The Logic of Scientific Discovery*, pp.410-418.

20. Popper, *The Logic of Scientific Discovery*, p.404.

21. Popper, The Logic of Scientific Discovery, Appendix *iv.
Note: to maintain a continuity of symbolism we will write 'p('x)' for Popper's 'P(X)' throughout.

22. Popper, *The Logic of Scientific Discovery*, pp.388-9.

23. Popper, *The Logic of Scientific Discovery*, p.418.

24. R.H. Vincent, "Popper on Qualitative Confirmation and Disconfirmation," *Australasian Journal of Philosophy*, 6 (1962), 159-66.

25. Popper, *Conjectures and Refutation: The Growth of Scientific Discovery*, p.390.

26. Henry Kyburg, *Probability and Inductive Logic* (New York: Macmillan and Company, 1970), pp.160-1.

27. Popper, *The Logic of Scientific Discovery*, p.410.

28. Popper, "Conjectural Knowledge: My Solution to the Problem of Induction," pp.183-88. *Revue Internationale de Philosophie* 95-6 (1971) fasc.I-2.

29. Popper, *Conjectures and Refutation: The Growth of Scientific Discovery,* see especially pp.112, 235, 240, 247 and 288.

30. J.W.N. Watkins, "Confirmation, the Paradoxes, and Positivism," in *The Critical Approach*, ed. Mario Bunge (New York: Free Press of Glencoe, 1964).

31. Popper, *The Logic of Scientific Discovery*, pp.388, 394-5, 419.

32. Popper, *The Logic of Scientific Discovery*, p.108.

33. Popper, *The Logic of Scientific Discovery*, p.400; and *Conjectures and Refutation: The Growth of Scientific Discovery*, pp.218-9.

CHAPTER IV

THE PARADOX OF THE RAVENS

With regard to the first question associated with A-acceptability--"Which hypothesis should I pick given the evidence which is at hand?"--the answers given by the Confirmatory Framework and by Popper are based on what each approach counts as evidence. The Confirmatory Framework syntactically characterizes "confirming evidence" and bases its response to this question in terms of a comparison of sets of confirming evidence statements by means of the subset relation; and Popper characterizes a "severe test report" and responds to this question in terms of the degree of severity of the tests passed by the hypotheses. In this chapter we will be concerned with a difficulty which has been seen to arise with respect to Hempel's characterization of "confirming evidence", and which, as we will try to show, can be seen to arise with respect to Popper's characterization of "severe test reports" as well. This difficulty was first discussed in detail by Hempel[1] and is usually referred to as the "Paradox of the Ravens".

The Paradox of the Ravens is not a logical paradox, since no logical inconsistency is uncovered. Rather the Paradox seems to point to an inadequacy in both approaches' characterization of evidence which confirms (corroborates) a hypotheses by indicating a disparity between what is identified to be confirming (corroborating) evidence and what is intuitively confirming (corroborating) evidence. We will see this difficulty to be a possible problem for both approaches to the issue of A-acceptability in the following respect: If the notions of confirming and corroborating evidence do not match up with our intuitions then selection procedures devised in terms of these notions may also be counter-intuitive. Moreover, the Paradox of the Ravens is a pertinent problem for us to discuss at this point since from our discussions here we will be able to extract certain problematic aspects of both approaches which will be of interest to us when we consider the more important question of the adequacy of these approaches in Chapter V.

In the thirty years since Hempel first discussed the Paradox of the Ravens response to the Paradox has tended to take two forms. On the one hand, following Hempel's lead, philosophers have argued that the Paradox is merely a "psychological illusion" which poses no serious difficulty for a confirmation theory in which it arises. On the other hand, many philosophers have found that the Paradox poses a serious difficulty for the confirmation theory in which it arises, and these philosophers have offered many ingenious attemps to avoid the Paradox. In this camp we find philosophers like J. Agassi, M. Black, I.J. Good, C.A. Hooker, J. Mackie, D. Pears, D. Stove, P. Suppes, R.H. Vincent, J.W.N. Watkins, and G.H. von Wright among others (for an overview of the various solutions proposed by these philosophers see R.G. Swinburne's article "The Paradoxes of Confirmation--A Survey"[2]). Interestingly enough, the philosophers who adopt the Popperian line concerning the problem of explicating confirmation are among those who, viewing the Paradox as a very serious difficulty, condemn Hempel's approach. On the whole, those who have written on the Paradox have considered it to be enough of a problem to warrant a second look at the issue of explicating confirmation.

After presenting the Paradox we will consider Hempel's proposed solution to it (as well as I. Scheffler's defense of Hempel), and then proceed to consider the question of whether or not Popper's approach can be seen to be immune from the Paradox. Our discussions will be drawn from a small portion of the literature on the Paradox and centered on the articles of D. Stove, J.W.N. Watkins, H. Alexander, J. Agassi, and J. Mackie.[3]

We will follow tradition and restrict our attention to hypotheses of a certain form, namely

Form I $(x)(\underline{P}(x) \supset \underline{Q}(x))$

where "$\underline{P}$" and "$\underline{Q}$" are predicate variables which take as values finite conjunctions or disjunctions of observation predicates or relations. To facilitate later discussions we will characterize four sorts of observation reports which will concern us by means of the following four sets of objects:

$$A = \{x: \underline{P}(x) \; \& \; \underline{Q}(x)\}$$
$$B = \{x: \sim\underline{P}(x) \; \& \; \underline{Q}(x)\}$$
$$C = \{x: \underline{P}(x) \; \& \sim\underline{Q}(x)\}$$
$$D = \{x: \sim\underline{P}(x) \; \& \sim\underline{Q}(x)\}$$

Observation reports which report objects which are elements of set A are those which intuitively confirm hypotheses of Form I, and reports which report objects which are elements of set C are intuitive falsifiers of such hypotheses. Observations reports which report objects from sets B and D are, as far as our preliminary intuitions are concerned, irrelevant or neutral observation sentences. Hereafter, once again in keeping with tradition, we will use as our example the hypothesis (of Form I) "All ravens are black", which we may symbolize by "$(x)(Rx \supset BX)$". For this hypothesis the set A will give us sentences reporting instances of black ravens, B sentences reporting black non-ravens (black shoes, for example), C sentences reporting non-black ravens, and D sentences reporting non-black non-ravens (white swans, for example). We will suppose that we have before us an observation report O which mentions n objects and which contains observation sentences of all four sorts (with the restriction that O is consistent). We will call the observation report which contains only the observation sentences in O which involve objects which are elements of set C the observation report O_f; and the set-theoretical difference between O and O_f will be called the observation report O_c.

The Paradox of the Ravens may be seen to be the result of the following propositions:

1. Nicod's Criterion: A confirming instance of a hypothesis is a positive instance, that is an observation report which asserts the fulfilment by an object of both the antecedent and the consequent conditions of a hypothesis of Form I.

2. Equivalence Condition: If an observation report confirms a hypothesis h_1, then it also confirms every hypothesis which is logically equivalent to h_1, for example, hypotheses of the following forms:

Form II $(x)(\sim\underline{Q}(x) \supset \sim\underline{P}(x))$,

Form III $(x)((\underline{P}(x) \; v \sim\underline{P}(x)) \supset (\underline{Q}(x) \; v \sim\underline{P}(x)))$.

From Nicod's Criterion it follows that observation sentences which mention objects from set A confirm hypotheses of Form I. However, by Nicod's Criterion and the Equivalence Condition it follows that observation sentences which mention objects from sets B and D also confirm hypotheses of Form I. Hence, given the hypothesis "All ravens are black" (and the development of that hypothesis for n objects) the observation report O_c directly confirms it, although O_c contains observation sentences which report the occurrence of black shoes and white swans. Furthermore, the observation report which mentions only the occurrences of black shoes and white swans directly confirms "All ravens are black" (given the appropriate development).

Why does the Paradox of the Ravens seem paradoxical? Simply because the observation of a white swan or a black shoe does not seem to constitute supporting evidence for "All ravens are black". It seems contrary to our intuitions that irrelevant evidence should be counted as confirmation for a hypothesis. It appears paradoxical to suggest, furthermore, that one might go about seeking information for the hypothesis "All ravens are black" without searching for ravens, or birds, or even black things. However, Hempel has argued that the impression of a paradox here is merely a "psychological illusion".[4] Before we consider Hempel's case we should state one last proposition which, although it does not help to generate the Paradox does figure into Hempel's conception of confirmation as well as his argument for the illusory nature of the Paradox:

> 3. The assumption of zero background belief: An adequate explicatum of the concept of confirming evidence may be one which makes no reference to background information or belief, other than the knowledge of what observation is represented by the predicates symbolized.

Hempel brings our attention to two considerations. First, there is a mistaken view that hypotheses of Form I, that is hypotheses of the form "All A's are B's", are about A's only, and hence that it is paradoxical that confirming evidence is about non-A's. Hempel agrees that "All ravens are black" asserts something about ravens (and not shoes or swans), but he claims that the question of what hypotheses assert, or what they are about, is a practical or psychological issue which has no influence on the logic of confirmation. The symbolic expression "$(x)(Rx \supset Bx)$" asserts only that any value of "x" whatsoever is either not R or is B. Consequently, it is not paradoxical, from a logical point of view, that observation reports mentioning non-R's and non-B's confirm the hypothesis "$(x)(Rx \supset Bx)$".

Hempel's second point is that the paradox only arises if additional information is introduced, and hence that we are judging one observation report to be confirming (e.g. a black raven report) but another not to be (e.g. a white swan report) on the basis of the hypothesis plus additional information. Hempel suggests that we consider the hypothesis "All sodium salts burn yellow", or "$(x)(Sx \supset Yx)$". If we hold a piece of pure ice over a colorless flame then we would not feel that the report that the flame did not turn yellow in any way supports the hypothesis, although, on Hempel's account, we would have confirming evidence since the resulting observation sentence would satisfy the transposed, equivalent hypothesis "$(x)(\sim Yx \supset \sim Sx)$". However, Hempel argues, if in another experiment some unspecified object "a" was held in a flame, and if the flame did not turn yellow and "a" was analyzed to find no sodium salts present, then the observation sentence concerning "a" would add support to "$(x)(Sx \supset Yx)$". But the only difference between the two experiments is that whereas the second concerns some unspecified object, the first concerns a substance which is specified to be pure ice and hence known, in terms of independent information, not to contain sodium salts. So, Hempel argues that without the assumption of zero background belief the psychological illusion of a paradoxical situation manifests itself; but, once this assumption is made, and the logical issue of confirmation is once again brought to the foreground, the Paradox disappears.

It appears that Hempel is directing his arguments against a view that there is a logical flaw in his Satisfaction Criterion which generates the Paradox of the Ravens. He argues that the Paradox is due to a "misguided intuition in the matter" and that there is no logical flaw involved. However, it may be readily granted that there is no logical flaw in Hempel's Satisfaction Criterion, but a logical flaw is not what is at issue in the Paradox of the Ravens. The Paradox is not a logical one; yet to say that the Paradox is merely "psychological" may just mean that Hempel's own condition of "material adequacy" is being violated. It is perhaps a misconception that hypotheses of the form "All A's are B's" are only about A's, but it would require more argument to convince a zoologist that the hypothesis "All ravens are black" is not only about ravens, but shoes, swans and symphonies as well. And given that a confirmatory logic is a tool intended for use by scientists, the assumption of zero background belief is clearly untenable: Scientists do not carry out experiments in an informational vacuum. Hempel has perhaps succeeded in isolating some of the reasons why the paradox makes us uncomfortable, but he has not explained why these reasons are out of place in a discussion of the material adequacy of his Satisfaction Criterion. Hence it could be argued that the Paradox of the Ravens points to a weakness of Hempel Satisfaction Criterion, namely that the Criterion produces a confirmation relation which is too wide insofar as there are good reasons (reasons based upon our intuitions about confirmation) for excluding certain observation sentences from the set of confirming evidence. If our intuitions are to be sacrificed on this issue then we certainly must have good reasons for abandoning them. Hempel has not given us good reasons for abandoning intuitions, rather than abandoning Nicod's Criterion or the Equivalence Condition. And in spite of the conflict between the intuitions we have and his Satisfaction Criterion, Hempel still insists that his Criterion does fit the intuitions of scientists.

It may be argued on Hempel's behalf that the expression "$Cf(e_1,h_1)$" is not intended to be an explication of what we usually have in mind when we say that evidence e_1 confirms hypothesis h_1, or that it is an explication of what we sometimes have in mind when we talk about confirmation. I. Scheffler has argued that Hempel was concerned to explicate one notion of confirmation, namely what we have in mind when we say that some evidence is "positive or favorable" to a hypothesis.[5] As an explication of the notion of "positive evidence" the relation "$Cf(e_1,h_1)$" need not take into account background belief or information or indeed anything else which is not strictly provided for by the Satisfaction Criterion. Now to argue that Hempel has a different explicandum in mind, one for which the Paradox of the Ravens is a result of "misguided intuition", would seem to save Hempel. However, Hempel has said that he intended to provide an explicatum of "that conception of confirmation which is implicit in scientific procedure and methodological discussion."[6] Is "positive evidence" such a conception of confirmation?

It is reasonable to ask supporters of Hempel to provide an argument showing that "positive evidence" is that conception of confirmation which is implicit in scientific procedure. Or, failing that, we would need an argument showing that this different explicandum which Hempel is considering is a useful one for the scientist. To argue that "positive evidence" is that conception of confirmation which is central to scientific methodology would require that the Paradox be viewed from a different perspective: It would have to be shown that the Paradox is the result of our misguided intuitions with regard to scientific procedure. However, if it is intuitively unsatisfactory to suppose that observations of black shoes and white swans confirm "All ravens are black", then it is clearly unsound practice to suppose this. Hempel does not offer any argument for the claim that "$Cf(e_1,h_1)$" is an explication of the notion of confirmation which figures in scientific practice; and indeed most commentators on Hempel's conception of confirmation vindicate him from the Paradox by arguing that his conception of confirmation is not a reflection of scientific practice, but is rather an idealization of some notion of confirmation. But, the question why this idealization of a notion of confirmation should have any use at all from the scoentists's viewpoint has not been satisfactorily answered.

In short, we cannot allow the Paradox to simply be passed off as a "psychological illusion" by Hempel without some admission that the notion of confirmation captured by "$Cf(e_1,h_1)$" is not what scientists have in mind. But then, how does Popper's theory of corroborability fare with respect to the Paradox? We can quite quickly show that the functor "$C(h_1,e_1,b)$" is at least susceptible to the Paradox: Suppose we let "h_1" be the familiar hypothesis about ravens, and "e_1" be an observation sentence which reports an object which belongs to either of the intuitively neutral sets, i.e., set B or D. Since our e_1 follows from h_1, it will be the case that $p(e_1,h_1)=1$, and if we suppose that the background knowledge in this case is such that e_1 is not a direct consequence of b, then it would follow that $p(e_1,h_1b)-p(e_1,b)>0$, from which it easily follows from the definition of the corroboration functor (see (6) of Chapter III, p.35), that $C(e_1,h_1,b)>0$, i.e., any observation sentence from either of the two neutral sets B and D can be said to corroborate the raven hypothesis.

A great deal of debating has been carried on between Popperians and critics concerning the issue of whether Popper's theory of corroborability does in fact fall victim to the Paradox or whether the theory has built-in safeguards which protect it from generating the Paradox. In what follows we will investigate the arguments for and against the contention that Popper's view of corroboration falls victim to the Paradox.

J.W.N. Watkins, an adherent to Popper's views, began a lengthy dispute by suggesting in "Between Analytic and Empirical" that the Paradox was wholly avoidable in a Popperian theory of corroboration.[7] Watkins apparently based this judgment on the passage in The Logic of Scientific Discovery where Popper writes that his corroboration functor can be adequately interpreted as the degree to which the evidence corroborates a hypothesis only if the evidence "consists of reports of the outcomes of sincere attempts to refute" the hypothesis.[8] Watkins writes:

> On a Popperian theory of confirmation this hypothesis ["All ravens are black"] is confirmed by an observation-report of a black raven, not because this reports an instance of the hypothesis--a white swan is also an instance of it--but because it reports a satisfactory test of the hypothesis; a raven has been examined unsuccessfully for non-blackness. On this view, statements about non-ravens which do not report tests of our hypothesis cannot confirm it.[9]

Watkins' view, then, is that the introduction of the notion of testing (i.e. attempting to falsify) saves Popper's theory of corroboration from the embarrassment of the Paradox.

On the face of it, Watkins' contention seems groundless, as I. Scheffler, D. Stove, and H.G. Alexander have all at one time or another shown.[10] First, inasmuch as Popper's talk of "sincere attempts to refute" is so vague, there is no reason to suppose that observations of black shoes and white swans will not be results of sincere attempts to refute "All ravens are black". Second, since an equivalence condition follows from Popper's Desiderata for $C(h_1,e_1,b)$, it follows that a sincere attempt to refute "All non-black things are non-ravens" is corroborating evidence (if the attempt does not result in refutation) for "All ravens are black" as well, and the Paradox reappears.

Watkins has responded to his critics by arguing that the Popperian insistence on testing at least limits the scope of the Paradox. Writing in response to Scheffler, Watkins states that whereas on Hempel's account of confirmation observations of black things and non-ravens "automatically" confirm "All ravens are black" Popper's theory has the consequence that the hypothesis "is confirmed by an observation-report that an object is a black raven, or black, or no raven, *only* if this reports a *test* of the hypothesis."[11] And, responding to Stove, Watkins notes that although the search for the non-black raven (i.e. the attempt to refute "All ravens are black")may well turn up white swans, still not *every* non-black non-raven or black object is the outcome of such a search.[12] J. Agassi, another Popperian, has argued in Watkins' defense. Agassi suggests that it is wrong to argue from the fact that on Popper's account non-refuting evidence *may* corroborate to the thesis that on Popper's account non-refuting evidence *always* corroborates.[13] The upshot of these defensive claims seems to be that Popper's theory of corroboration does not fall victim to the Paradox because the factor of testing is an impartial condition which is placed on evidence in order for it to be confirming.

How does Popper's corroboration functor impose this condition on observation reports? As we have noted in the preceding chapter, one of the conditions which determines the value of $C(h_1,e_1,b)$ is the probability of e_1 given h_1 as compared to the probability of e_1 given b, the background knowledge. The "severity" functor $S(e_1,h_1,b)$ gives us that the severest test of h_1 is that test resulting in an observation report e_1 which is such that the value of $p(e_1,b)$ is very low while the value of $p(e_1,h_1b)$ is very high. How might this measure of the "severity" of test reports be applied to the case of the raven hypothesis? We may suppose that the background knowledge here consists only of the statement that the number of black objects is indefinitely larger than the number of ravens. Further, we may suppose that we have only four observation reports: e_1= "This object is a non-raven", e_2= "This object is black", e_3= "This is a black raven", and e_4= "This is a non-black raven". If h_1 is "All ravens are black", then it would appear that the values of $p(e_1,h_1b)$ and $p(e_2,h_1b)$ would be very close to the values of $p(e_1,b)$ and $p(e_2,b)$, respectively. But since h_1 increases the probability of e_3 and reduces to zero the probability of e_4, we would have $p(e_3,h_1b) > p(e_3,b)$ and $p(e_4,h_1b)=0 < p(e_4,b)$. Clearly something is being indicated by these values, but it is not apparent that the factor of testing has been thus isolated. It seems correct to say however, that the values of the initial probabilities of h_1 and the four observation reports reflect only a mathematical relationship between statements and that how we may have acquired these observation reports is not reflected in these values.

There is surely no way for the scientist to anticipate what observation report will result from the activity of searching for a refutation of a hypothesis. But then the probability values of the expressions $p(e_1,h_1b)$ and $p(e_1,b)$ may very well give the result that e_1 is a "severe test" of h_1 when that is not remotely the case. Let us suppose that we are engaged in a sincere attempt to refute the hypothesis "All migratory birds are large and fly south in the winter". Let us further suppose that our background knowledge about birds contains the statement "No raven is large". If in our search for the migratory bird which is small and flies north for the winter we should come across a large migrating raven (but are unable to determine which direction this bird migrates in the winter), then it will be the case that this report of a test, e_1, is such that $p(e_1,b)=0$. But since $p(e_1,h_1b)$ will be significantly greater than zero we should have to say that e_1 is a severe test of h_1. Here the "severity" of a test is determined by the nature of the background knowledge. Furthermore, the degree of corroboration of this hypothesis by the report of a large migrating raven may be larger than the degree of corroboration provided by the report of a large, southward-migrating sparrow if this report does not conflict with the background knowledge.

Although Watkins and Agassi argue that Popper's theory of corroboration limits the scope of the Paradox of the Ravens, it is clear that this is not accomplished by the formal properties of the corroboration functor. Stove, in response to Watkins, has argued that at bottom Popper's corroboration functor rests on a psychological assumption, namely that the scientist is sincere in his desire to refute.[14] To this charge Watkins has responded that the objective measures provided by Popper's functors completely avoid any talk about the intentions of scientists or their sincerity.[15] But here Watkins is just arguing against himself, for since the functors cannot reflect sincerity of testing, and since it is this factor which gives some plausibility to the claim that the scope of the Paradox is limited, Watkins' claim that Popper's functors are "objective measures" amounts to the admission that the Paradox appears in full force in Popper's theory. In fact Watkins' case for saying that the statement "Scientist A is more sincere in his testing of h_1 if the outcome of his test is the report e_1, rather than e_2" can be replaced by $p(e_1,h_1b)-p(e_1,b) > p(e_2,h_1b)-p(e_2,b)$" faces two problems: (1) The value of "$p(e_1,h_1b)-p(e_1,b)$" can not be argued to reflect the "sincerity" of the test report e_1 (indeed, as we have seen, the value of this expression may only reflect an irrelevant relation between the test report and the background knowledge); (2) the observation reports which are symbolized by "e_1" and "e_2" in the probability expressions are outcomes of testing, they are test reports; but Watkins does not provide an explanation of how the desire to refute should affect the reports of the outcome of tests.

Watkins employs another tactic to try to show that the Paradox is neutralized by Popper's requirement of testing. Watkins suggests that evidence will count as confirming only if we had "reason to suspect" that it was a counter-instance to the hypothesis. Thus, if in our search for the falsifying evidence for "All ravens are black" we should discover four objects such that (i) object _a_ is non-black, (ii) object _b_ is a raven, (iii) object _c_ is a non-raven, and (iv) object _d_ is black, then we would have reason to suspect that objects _a_ and _b_ might, upon further investigation, lead to the falsification of the hypothesis. Furthermore, objects _c_ and _d_ could not lead to falsification, since the information we have about them precludes the possibility that they would be counter-instances. Watkins argues that since we "already know" that objects _c_ and _d_ will not lead to the falsification of "All ravens are black", whatever else is discovered about them will not count as confirmation.[16]

By introducing a time factor into the acquisition of evidence Watkins is trying to convince us that there is an asymmetry between the two reports "There's a raven...Look, it's black" and "There's something black...Look it's a raven". From a logical point of view there is no difference between these two observation reports--if one confirms then the other must confirm as well.[17] The only difference between these two observation reports is that difference generated by the "intention to falsify" requirement. But, clearly, this requirement is not part of Popper's corroboration functor, and if it is to be brought to bear on the question of when evidence confirms then it must be added on to Popper's functor in the form of a non-logical requirement. Consequently, Watkins has failed to show that Popper's corroboration functor, as a formal expression, avoids the Paradox insofar as he has failed to show how either the "sincerity in testing" or the "intention to falsify" requirements are built into the definition of Popper's functors. But if Watkins' case does not go through then we are left with our original claim that Popper's theory of corroboration is prey to the Paradox of the Ravens.

We will now consider two of the many refinements of Hempel's theory of confirmation and Popper's theory of corroboration which have been proposed in the face of the problems posed by the Paradox. In both cases it has been argued that Hempel's theory is vindicated as a theory about confirmation in an "ideal" sense for which the Paradox is harmless.

H.G. Alexander has argued that the assumption of zero background belief is the source of our discomfort about the paradox.[18] Given a hypothesis asserting that all A's are B's, Alexander asks what is presupposed when it is said that something which is both an A and a B confirms while something which is neither does not confirm. Alexander answers that part of our background knowledge about A's and B's involves the belief as to the relative populations of A's and B's. If we suppose that the probability of any object being an A is x and the probability of it being a B is y, then if there is no correlation between something being an A and it being a B the distribution would be

A & B	A & ∼B	∼A & B	∼A & ∼B
xy	x(1-y)	y(1-x)	(1-x)(1-y).

However, if the hypothesis "All A's are B's" were true, then the distribution would be

x	---	y-x	1-y.

This being the case, it would seem that observations of objects which are both A and B would provide better confirmation than observations of objects which were neither only if the probability of something being an A was less than the probability of something being a non-B. That is, since the number of ravens is considerably smaller than the number of non-black things, we feel that finding a black raven provides better confirmation for "All ravens are black" than finding a non-black non-raven. However, for other hypotheses where the number of non-B's is considerably greater than the number of A's, e.g., "All deciduous trees are less than 200 feet tall", we would accept observations of objects which are neither A nor B (i.e. trees which are over 200 feet tall and coniferous) as confirmation.

As an explanation of why the Paradox is discomforting, Alexander's comments do seem satisfying. However, on Alexander's account it is still the case that observations of white shoes confirm

"All ravens are black", although they do not confirm as much as observations of black ravens. And for the case of "All deciduous trees are less than 200 feet tall", although we are motivated by the additional background knowledge that there are few trees over 200 feet tall to count coniferous trees over 200 feet tall as confirming, still we may not be content to say that a 200 foot mountain also provides confirmation. But most importantly, it is not clear how the addition of information concerning the relative population of the A's and the non-B's for hypotheses of the form "All A's are B's" would come to the aid of Hempel's theory. Even if it were possible to assign probability values to occurrences of A's and non-B's (i.e. even if we could determine the relative populations to the degree of accuracy required by the hypothesis in question), still this would not alter Hempel's theory. If we could devise a quantitative theory of confirmation based upon Hempel's theory where these probability values could be introduced, then we would seem to have a theory which could assign different degrees of confirmatory power to different observations. But here too the intuitively neutral observation reports would be assigned some degree of positive confirmation; they would, in short, still confirm. But more importantly, Alexander's suggested modification of Hempel's theory would make Hempel's theory into a quantitative theory; but Hempel's expressed interest was in a qualitative theory.

J.L. Mackie has rightly identified the source of the Paradox of the Ravens with the intuition that observations of black shoes and white swans are neutral to "All ravens are black".[19] However, Mackie argues that given the assumption of zero background knowledge Hempel's solution to the Paradox (i.e. the denial that black shoes and white swans are neutral to "All ravens are black") is adequate. Furthermore, Mackie argues that Alexander's modification seems to provide another solution to the Paradox inasmuch as it explains our intuitions with regard to the neutrality of black shoes and white swans. Mackie goes on to explain why Watkins' solution to the Paradox is also adequate. It is only this last section of Mackie's article which we shall consider.

We have argued above that Watkins has not provided an explanation why the desire to refute a hypothesis should have any affect on the outcome of such tests. Mackie proposes to fill this lacuna by noting that the activity of looking for or trying to find something raises the chances that what is sought after will be found. Hence, by adopting a procedure of trying to falsify a hypothesis we raise our chances of falsifying it, if it is false. If we add to our background knowledge the fact that we are looking for non-black ravens, then the observation report e_1 which states that we have found a black raven is made more probable by the hypothesis "All ravens are black", and hence $p(e_1,h_1 b) > p(e_1,b)$. On the other hand, if we add to our background knowledge the fact that we are not looking for non-black ravens, then the hypothesis will not raise the probability value of the observation report that a black raven has been found, that is, $p(e_1,h_1 b)=p(e_1,b)$.

How might Mackie's modification help Watkins? Mackie has proposed that the Popperian requirement of "intention to refute" can be translated into the corroboration functor so that the fulfillment of the requirement in particular cases has an affect on the value of the functor. By adding to the background knowledge the fact that a policy of falsification or testing is being engaged in, the outcome of this policy, the observation report e_1, will have a higher relative probability value with the hypothesis added to the background knowledge than it does with the background knowledge alone. This modification does seem to help Watkins since he can now argue that (i) if the value of $C(h_1,e_1,b)$ is strictly greater than zero, and (ii) if e_1 is the outcome of a policy of falsification, or attempting to refute h_1, and (iii) if the fact that this policy is being undertaken is added to the background knowledge, then e_1 corroborates h_1, whatever e_1 may be.

The argument that the observation of a black shoe corroborates "All ravens are black" if and only if the observation is the outcome of a policy of testing seems now to turn on a requirement imposed on the set of background statements. From a logical point of view, it does not matter whether the experimenter is in fact engaged in such a policy or not, as long as the background knowledge includes a statement that he is. And this is surely suspicious. Moreover, it is simply false that a scientist must be engaged in a policy of falsification if the outcome of his testing is to count as corroboration of a hypothesis; surely, a scientist may simply be carrying on experiments which are not undertaken with the goal in mind to falsify or corroborate any hypothesis; yet if later a hypothesis is formulated it would be odd to deny that the previously established test results can not count as falsification or corroboration. It should be recalled that the original argument supplied by Watkins was that since Popper's corroboration functor determines the degree to which evidence supports or confirms a hypothesis only if the evidence is the result of a sincere attempt to refute the hypothesis it is not really paradoxical for neutral-seeming evidence to be evaluated as corroborative. Watkins' attempts to rid the testing requirement of its psychological character failed; but Mackie's suggestion to rid this requirement of its psychological character by simply adding an "intention to falsify" statement to the set of background statements makes the requirement into a silly ritual. Whatever force the testing requirement may have at the beginning has been lost by these attempts either to suppose it is somehow built into the functors themselves or to add a statement of the requirement to the set of background statements.

Popper is quite content to keep his testing requirement complete with all its psychological overtones simply because "one cannot completely formalize the idea of a sincere and ingenious attempt [at the refutation of a hypothesis]."[20] With this unformalizable requirement always in the background of Popper's arguments, Popper consistently overlooks the fact that experimental results need not be the results of sincere and ingenious attempts at the refutation of a hypothesis. (And this points to a very limited conception of scientific methodology which, as we will see in the next chapter, Popper holds to). At bottom the only argument in support of the claim that on Popper's account it is not really paradoxical for black shoe or white swan observations to corroborate "All ravens are black" is just that the reports of the outcomes of sincere attempts to refute a hypothesis must always result in either falsification or corroboration. But this is surely false. In actual practice it is clear that scientists recognize three sorts of experimental findings, those which confirm a hypothesis, those which refute it and those which are wholly or partially irrelevant to the hypothesis.

In this chapter we have tried to show that the Paradox of the Ravens seems to be a difficulty for both the Confirmatory Framework and Popper insofar as our intuitions seem to be at variance with respect to both approaches' characterization on confirming (corroborating) evidence. The Paradox, if we decide to trust our intuitions on this matter, results from the fact that for both approaches certain sorts of neutral or irrelevant evidence are classed as confirming (corroborating) evidence. This is not to say that neither Hempel nor Popper recognize evidence which is neutral: An observation report is neutral for Hempel if it neither entails the development of a hypothesis for the objects mentioned in it nor entails the development of the negation of the hypothesis for the objects mentioned in it. And for Popper neutral evidence is any e_1 which is such that $p(e_1,h_1b)-p(e_1,b)=0$. However, the Paradox seems to suggest that the set of neutral evidence is, for both approaches, much more extensive than is allowed for.

If we felt strong enough about the intuitions which the Paradox elicits, then we might want to go on to claim that both approaches are inadequate as bases for a response to the first question of A-acceptability. (And if we did go on to make this strong claim then we would have a basis on which to argue that Popper's theory fares better on the issue of A-acceptability for the following reason: Both approaches are inadequate with regard to the first question of A-acceptability, but the Confirmatory Framework is also inadequate with regard to the second question of A-acceptability since whatever qualms we have against actual evidence which seems neutral being classed as confirming, would also apply to possible evidence, which seems neutral, being classed as confirming. Popper's answer to the second question of A-acceptability does not fall victim to the Paradox since it does not mention evidence at all.) However, we shall not go on to argue in this way for two reasons: (i) Intuitions with regard to what should constitute neutral evidence may not provide a sound basis for such a claim, and a glance at the literature surrounding the Paradox of the Ravens will show that different intuitions on this matter are possible; and (ii) there are sounder bases upon which to judge the adequacy of these two approaches (with respect to both questions of A-acceptability), and these will be considered in the next chapter.

FOOTNOTES TO CHAPTER IV

1. First noted by Hempel in "Le Probleme de la Vérité," Theoria, Vol.3 (1937), pp.206-46. Treated fully in Hempel "Studies in the Logic of Confirmation," pp.14-20. Also treated by J. Hosisson-Lindenbaum in "On Confirmation," Journal of Symbolic Logic 5 (1940), pp.133-48.

2. R.G. Swinburne, "The Paradoxes of Confirmation--A Survey," American Philosophical Quarterly, Vol.8, No.4 (Oct. 1971), pp.318-330.

3. Some of the articles in which these philosophers have expressed their views on the Paradox of the Ravens are the following:
   (i) J. Agassi, "Corroboration Versus Induction," British Journal of the Philosophy of Science, Vol.9 (1959), pp.311-17.
   (ii) H. Alexander, "The Paradoxes of Confirmation," British Journal of the Philosophy of Science, Vol.9 (1958), pp. 227-33.
   __________, "The Paradoxes of Confirmation--A Reply to Dr. Agassi," British Journal of the Philosophy of Science, Vol.10 (1960), pp.229-34.
   (iii) C. Hempel, "Empirical Statements and Falsifiability," Philosophy, Vol.33 (1958), pp.342-48.
   (iv) J.L. Mackie, "The Paradox of Confirmation," British Journal of the Philosophy of Science, Vol.13 (1963), pp.265-77.
   (v) I. Scheffler, "A Note on Confirmation," Philosophical Studies, Vol.11 (1960), pp.21-23.
   __________, "A Rejoinder on Confirmation,", Philosophical Studies, Vol.12 (1961), pp.19-20.
   (vi) D. Stove, "Popperian Confirmation and the Paradox of the Ravens," Australasian Journal of Philosophy, Vol.37 (1959), pp.149-51.
   __________, "A Reply to Mr. Watkins," Australasian Journal of Philosophy, Vol.38 (1960), pp.51-54.
   (vii) J.W.N. Watkins, "Between Analytic and Empirical," Philosophy, Vol.33 (1957), pp.112-31.
   __________, "A Rejoinder to Prof. Hempel's Reply," Philosophy, Vol.34 (1958), pp.349-55.
   __________, "Confirmation without Background Knowledge," British Journal of the Philosophy of Science, Vol.40 (1960), pp.318-20.
   __________, "Prof. Scheffler's Note," Philosophical Studies, Vol.12 (1961), pp.16-19.
   __________, "Mr. Stove's Blunders," Australasian Journal of Philosophy, Vol.37 (1960), pp.240-1.
   __________, "Reply to Mr. Stove's Reply," Australasian Journal of Philosophy, Vol.38 (1960), pp.54-8.

4. Hempel, "Studies in the Logic of Confirmation," p.18 and p.20.

5. I.Scheffler, The Anatomy of Inquiry (New York: Knopf, 1963), pp. 276-78.

6. Hempel, "Studies in the Logic of Confirmation,", p.34.

7. J.W.N. Watkins, "Between Analytic and Empirical,", pp.116-7.

8. Popper, The Logic of Scientific Discovery, p.414.

9. J.W.N. Watkins, "A Rejoinder to Prof. Hempel's Reply," p.351.

10. I. Scheffler, The Anatomy of Inquiry, pp.269-74; D. Stove "Popperian Confirmation and the Paradox of the Ravens," pp.150-1; H. Alexander, "The Paradoxes of Confirmation," pp.228-9.

11. J.W.N. Watkins, "Prof. Scheffler's Note,", p.18.

12. J.W.N. Watkins, "Mr. Stove's Blunders,", p.240.

13. J. Agassi, "Corroboration Versus Induction," pp.312-3.

14. D. Stove, "A Reply to Mr. Watkins," p.51 and p.53.

15. J.W.N. Watkins, "Reply to Mr. Stove's Reply," pp.55-6.

16. J.W.N. Watkins, "Prof. Scheffler's Note," p.17; and J.W.N. Watkins, "Confirmation without Background Knowlegde," p.319.

17, Indeed, Watkins seems to assume that the hypothesis under consideration is not "All ravens are black", but rather "All ravens are black, and you notice that something is a raven before you notice that it is black". For this last hypothesis asymmetry between the two reports mentioned in the text could indeed be argued for.

18. H. Alexander, "The Paradoxes of Confirmation," pp.229-30.

19. J.L. Mackie, "The Paradox of Confirmation," p.265.

20. Popper, The Logic of Scientific Discovery, p.402.

CHAPTER V

A-ACCEPTABILITY

We have supposed that the Paradox of the Ravens should not be seen as a sufficient reason for claiming that both the Confirmatory Framework and Popper's approach are inadequate for the analysis of A-acceptability. However, the issues which have been raised in the course of our discussion of the Paradox can be seen to warrant the suspicion that the preference policies of both approaches are inadequate with regard to both questions associated with A-acceptability. Whereas in Chapter IV we were interested in the two different notions of evidence presupposed by the two approaches, here we will be interested in the two different notions of preferred hypotheses which these two approaches generate. Hence, our concern here will be with the two definitions of A-acceptable hypotheses given by the two approaches, i.e. Definitions 2-4 and 3-4.

The considerations which will be brought to bear on the adequacy of these two definitions of A-acceptable hypotheses will be considerations which affect the ways both approaches respond to both questions of A-acceptability. We will be relying on different intuitions in this chapter, namely those which designate the intuitively preferable of two hypotheses. It should be noted that we are viewing the activity of expressing a preference for a hypothesis to be different from that of A-accepting a hypothesis. The procedure of A-accepting a hypothesis we take to be the result of the evaluation of several selection criteria, the assignment of relative weights to the different criteria, and perhaps as well the consideration of other factors such as limitations of funds, time, manpower, and so on. On the other hand, a hypothesis is preferred on the basis of a single selection criterion. This difference between preferring and A-accepting will become important when we discuss Popper's approach to A-acceptability since--given that corroborability is envisioned to be the same as A-acceptability--the distinction between A-acceptability and preferability collapses. And for the Confirmatory Framework too the distinction we wish to draw can be seen to partially collapse since the fact that h_1 is preferred to h_2 on the basis of Definition 2-4 is a sufficient reason to claim that h_1 is A-acceptable (unless there is a third hypothesis which is preferred to both h_1 and h_2 on the basis of Definition 2-4). Later in this chapter we will argue against the claim that a single selection criterion can be sufficient to respond to both questions of A-acceptability. And later in this chapter we will also try to show that Popper's criteria of A-acceptability can best be seen as criteria of B-acceptability.

Our first task will be to show that both explicata are unsatisfactory in the weak sense mentioned in Chapter I, namely that they tend to judge the intuitively less preferable hypothesis to be at least as preferable as the intuitively preferable hypothesis. In what follows we will be especially interested in how the Confirmatory Framework and Popper respond to the second question associated with A-acceptability, and as a consequence our comments will be directed towards the two comparative relations $CF(h_1,h_2)$ and $CP(h_1,h_2)$. However, all of what is to follow can be applied to the responses given by the two approaches to the first question associated with A-acceptability with only slight modifications necessary in the arguments given. We will begin by considering the adequacy of the Confirmatory Framework's definition of A-acceptable hypotheses and the selection criterion given by $CF(h_1,h_2)$.

Our first consideration will be that of the assumption of zero background knowledge. Alexander and Mackie have both defended Hempel against the claim that the Paradox of the Ravens is harmful to Hempel's conception of confirmation by pointing out that Hempel forbids the introduction of additional, or background, information. In constructing the Confirmatory Framework's explicatum of comparative confirmability we have purposely followed Hempel in this respect. We must now consider how the exclusion of background information affects the adequacy of $CF(h_1,h_2)$ as a selection criterion.

Since selection criteria are to help the scientist decide between rival hypotheses it is clear that the assumption of zero background knowledge is untenable. The context of the problem of A-acceptability is senseless if we suppose that no auxiliary information is available to the scientist. The scientist approaches the problem of choosing between rival hypotheses not only with experimental results on hand but also with various beliefs concerning the field of application of the two hypotheses. These beliefs may involve a whole tradition built upon one or more entrenched hypotheses, or these beliefs may involve hypotheses in other areas which are put into a different light by one or other of the two hypotheses. Hempel's efforts at providing a neutral and wide notion of evidence fail to account for the fact that "observation reports" may at times be informative and valuable to the scientist only by virtue of background information. Hempel's notion of evidence supposes that confirming or disconfirming evidence is always a literal description of the world (namely, a conjunction of "observational predicates"); yet it seems indisputable that such a description could not constitute evidence for or against a hypothesis unless it is seen in terms of the scientist's stock of background knowledge.

For example, if we are concerned with hypotheses dealing with the mechanics of gases, it is likely that our "observation reports" will be reports of the readings of certain instruments taken at certain times and under certain conditions. To make sense of these readings we need, at least, auxiliary hypotheses which serve to correlate, say, the position of a pointer on a gauge with a measure of some specific property of a gas. But we need as well the kinetic theory of gases, namely the assumption that the atoms making up the gases are more or less spherical and collide randomly with each other without affecting their internal structures. Whatever evidence we have concerning hypotheses about aspects of the mechanics of gases is thus in a sense interpreted by this previously established hypothesis, and without this and other hypotheses--with zero background knowledge--no correlation between the hypotheses and the "observations" can be made.

This would lead us to suspect that the selection criterion $CF(h_1,h_2)$ may favor hypotheses which, given the background information, would not be preferred. Suppose we have two hypotheses to choose between. The first, h_1, asserts that there is some mathematical relationship between two properties of gases. If we suppose that these properties are not directly observable but can only be measured by certain instruments, then we may think of another hypothesis, h_2, which asserts that there is a mathematical relationship between the readings of these instruments. The class of satisfiers, S_n, relevant here will consist of reports of the readings of instruments given different test conditions. Since the observation reports in S_n do not mention the properties referred to by h_1, but do mention the observable events referred to by h_2, it follows that S_n is the set of satisfiers of h_2 alone; indeed, the set of satisfiers of h_1 will be empty since no observation report could entail h_1 (for the appropriate development). So, with the correlation of the readings with the properties of gases, it will of course be the case that CF(h_2,h_1), although with the correlation provided by the background information which is relevant here both hypotheses are equally well confirmed. We would naturally have other grounds for preferring h_1 to h_2, but the point to be made here is that on the assumption of zero background knowledge hypotheses which assert a relationship between unobservable properties will be less preferable to hypotheses which assert a relationship between the observable readings of the instruments used to measure these properties.

It would seem on first glance that Hempel's distinction between direct confirmation and confirmation would come to the aid of CF(h_1,h_2) in cases like these. In other words, it would seem that the observation reports included in S_n, although they are clearly not direct satisfiers of h_1, may simply be satisfiers of h_1. To make this case it would be required to show that the set of statements K which entail h_1 (and each element of which is directly confirmed by S_n) is just the set of auxiliary hypotheses which allow us to correlate readings of instruments with properties of gases. The difficulty with this suggestion is that none of the statements of K could correlate readings with properties: We normally think of the function of auxiliary hypotheses as that of, in effect, translating statements about observable events into statements about less directly observable, or entirely unobservable, properties, e.g. "The greater the number pointed to by the needle on gauge X the greater the pressure of gas Y." But then the observation reports of S_n, which contain only observational predicates, can not directly confirm such an assertion. Likewise, these auxiliary hypotheses could not entail a hypothesis like h_1 since they serve to correlate observable events with unobservable properties. It is possible for a hypothesis to be entailed by the background information, but when the hypothesis employs predicates which are not observational, Hempel's confirmation relation excludes the possibility that observation reports will confirm it. As a consequence, the selection criterion $CF(h_1,h_2)$ will never prefer a hypothesis which employs predicates which are not observational since the set of satisfiers for that hypothesis will be empty.

In brief, the assumption of zero background knowledge does not accord with scientific practice, nor is it conceivable that a choice between hypotheses which contain predicates referring to unobservable properties could be attempted on the basis of this assumption. Moreover, it is not at all clear that we could legitimately restrict the set of confirming evidence by claiming that confirming evidence must involve the direct observation of objects, events or properties of objects and events. Rather, it could be argued that without a theoretical framework provided by the background information many observations would be without importance: One does not observe the production and absorption of a mason in the photographic emulsion or the cloud chamber; one observes lines moving in many directions. So rather than proceeding on the assumption of zero background knowledge--in the hope of simplifying the syntactical form of a confirmation relation--we should base any notion of confirmation on the fact that evidence seems to be dependent on the background information.

It would appear that Hempel is faced with two options with regard to background knowledge and its role in the confirmation or disconfirmation of hypotheses. Either Hempel is committed to the view that his conception of confirmation is applicable to scientific problems when and only when we have no additional background information on hand, or to the view that background information can be added to the confirmation relation. The first option is, as we have tried to show, unacceptable. The second option would be acceptable if Hempel's confirmation relation were such that background knowledge could be added. However, in the relation $C(h,e)$ there are only two places where this additional information could be fit in, either conjoined to the hypothesis h, or to the observation report e.

Let us suppose that $C(h,e)$ holds and that we wish to fit in some set of relevant background statements, b, into the first place of the relation. Now it is clear that if $C(h,e)$ holds then the augmented relation $C(h \& b,e)$ would generally not hold for the reason that the statements in b would contain predicates not occurring in e. On the other hand, let us suppose that $C(h,e)$ holds and that the set b and the observation report e are consistent and that we wish to add the background knowledge to the second place in the relation, obtaining $C(h, e \& b)$. We first note that if our background knowledge is to successfully fit into the second place of the confirmation relation it can not contain quantified expressions, i.e., b must be seen to be some finite conjunction of observation reports. But, as we have seen, it would be inappropriate to characterize the background knowledge which a scientist brings to a consideration of the relation between evidence and a hypothesis as solely a set of particular statements about past observations. But we also notice that the statement $C(h, e \& b)$ would not hold if b happened to contain partial observation reports; e.g. if h is $(x)(Rx \supset Bx)$ and the background knowledge contained the statement $\sim Bb$ but not the statement $\sim Rb$, then $C(h,e \& b)$ would not hold even if $C(h,e)$ did. But it is reasonable to suppose that background information would contain partial reports, that it would contain, for example, the statement that some object was observed not to be black but whether or not it was a raven could not be determined. In short, this second option does not seem to be available to Hempel simply because his confirmation relation cannot accommodate the addition of background knowledge.

We can now turn to the "weaker preferring" characteristic of

$CF(h_1,h_2)$ which was established by Theorem 2-5. (What we will show below can be applied to any explicata of comparative confirmation for which Theorem 2-5 holds.) We first introduce by examples the notion of a "safe" hypothesis. A "safe" hypothesis will be one which results from the pseudo-scientific activity of saving a genuine hypothesis from possible falsification--hence a "safe" hypothesis will be objectionable for the same reasons that an *ad hoc* hypothesis is. (Our examples will be drawn from research centering around the chemical serotonin which is found in the human brain and its role in the coordination and integration of smooth muscle movements.)

We may suppose that research in the area of brain chemistry has given *prima facie* credibility to the hypothesis

> h_n "Whenever the level of serotonin is lowered in a test subject (as the result of the injection of serotonin-inhibiting chemicals) aberrant behavior is observed."

The hypothesis h_n may be expressed in the language of $CF(h_1,h_2)$ by the expression "$(x)(Sx \supset Ax)$" (this is of course a simplified translation, but it is not simplified to the extent that the general form of h_n is obscured). The set of satisfiers of h_n will consist of observation reports of, say, the injection of certain chemicals into a test subject and of observed behavior. (The problems we have noted with regard to the correlation of observations and properties which are not directly observable applies here as elsewhere; but we may agree to set them aside for the purposes of the example.)

With h_n on hand, the following assertions will constitute some of the "safe" versions of h_n:

> h_{m1} "Whenever the level of serotonin is lowered in a test subject, either aberrant behavior is observed or the test subject covers up his lack of coordination of movement."

> h_{m2} "Whenever the level of serotonin is lowered in a test subject, either aberrant behavior is observed or the level of serotonin was not significantly lowered."

h_{m3} "Whenever the level of serotonin is lowered in a test subject, either aberrant behavior is observed or it is not."

In each case the "safe" hypothesis saves h_n from a falsifying test result, namely the test in which the subject did not exhibit behavior after the injection of serotonin-inhibiting chemicals. It should be clear both that there are an unlimited number of alternative "safe" versions of h_n and that h_{m3}, being a tautology, is the "safest" of them all, indeed it is entailed by any hypothesis. Translating the two "safe" hypotheses h_{m1} and h_{m2} by the expressions "$(x)(Sx \supset (Ax \vee Cx))$" and "$(x)(Sx \supset (Ax \vee \sim S'x))$" we see that since "$(x)(Sx \supset Ax)$" entails both of these expressions it follows by Theorem 2-5 that it is never the case that either $CF(h_n, h_{m1})$ or $CF(h_n, h_{m2})$. More generally, since we can, for any genuine hypothesis, construct "safe" versions of it, any "safe" hypothesis is at least as preferable as the hypothesis which has been thus saved. So, from the fact that $CF(h_1, h_2)$ is "weaker-preferring" those assertions which result from genuine hypotheses by the sort of trivial procedure exemplified by h_{m1} and h_{m2} are always at least as preferable as those hypotheses themselves. We will mention another unfortunate result of Theorem 2-5 before going on.

In many cases, the fact that evidence confirms a relatively strong hypothesis is more significant to the scientist than the fact that the same evidence confirms a weaker version of the hypothesis. For example, if research has indicated that there is a disease d which is found mostly in slums of large cities then one hypothesis which a scientist might want to consider is that some specific feature of slum-living contributes to the slum dweller's chances of having d once in his life. We may suppose that certain evidence supports this hypothesis. Yet, this same evidence will support the weaker version of this hypothesis, namely the hypothesis that there is some, unspecified feature of slum-living which contributes to the slum dweller's chances of having d once in his life. Now by Theorem 2-5 the weaker hypothesis would be at least as preferable as the stronger one. But surely the hypothesis which asserts a correlation between a specific feature of slum-living and the chances of having the disease is much more valuable to the scientist than the weaker hypothesis. Because the feature of slum-living is specified in the strong hypothesis, the scientist can better direct his experiments, focusing his attention on one, rather than a myriad of features which might cause the disease. In short, the selection criterion provided by CF(h_1,h_2) does not account for the fact that the value of confirming evidence may differ for different hypotheses, and the formal quality of "satisfaction" can not accommodate this subtlety.

Our last consideration concerns the "language" in which the selection criterion CF(h_1,h_2) is constructed, namely predicate calculus without identity. The Paradox of the Ravens, if we trust our intuitions, is a difficulty which may be traced to the syntactic features of the implication and equivalence relations. The classificatory concepts, and CF(h_1,h_2) as well, are modelled after the entailment relation which functions within the scope of the axioms and rules of a logical calculus. Within predicate calculus we have clear rules for determining when expressions are well-formed, when one follows from another, when one is logically equivalent to another, and so on. The difficulty with the project of constructing a "purely syntactical" confirmation relation (be it classificatory, comparative or quantitative) which is at the same time "materially adequate" is a function of the link between symbolic expressions and evidence statements and hypotheses.

From what we have already said about the inadequacy of the "observational predicates" capturing even the simplest instances of scientifically acceptable evidence, it would follow that the language of CF(h_1,h_2) is inadequate for the purposes of symbolizing evidence and hypotheses which employ non-observational or theoretical terms. Moreover, inasmuch as the language in terms of which Hempel's Satisfaction Criterion is formulated is first-order predicate calculus without identity, a large class of hypotheses--those which assert a quantitative relationship between objects or properties of objects--will not be translatable. Hempel was quite sensitive to the paucity of the language he chose, and he has suggested that his definition of confirmation should be expanded to become applicable to more complex languages.[1] Since no such expansion of Hempel's definition of confirmation has been undertaken it is impossible for us to consider the adequacy of the symbolism involved. We can suggest, however, that as it stands the language of CF(h_1,h_2) is not rich enough to handle all the evidence statements and hypotheses which scientists consider.

Our examination of the selection criterion CF(h_1,h_2) dealt with three considerations: (i) The assumption of zero background knowledge, (ii) the "weaker-preferring" characteristic of CF(h_1,h_2), and (iii) the language of CF(h_1,h_2). Our concerns with regard to CP(h_1,h_2) as an adequate explicatum of a selection criterion parallel these three considerations. We will first consider the role played by background knowledge in CP(h_1,h_2). Secondly, we will analyze the consequences of the "stronger-preferring" characteristic of CP(h_1,h_2); and lastly, we will consider the language of CP(h_1,h_2) with its inclusion of probability statements.

While characterizing background knowledge Popper presents a picture of an ever-increasing, tentatively accepted, body of beliefs and information (old theories and old test results) for which new hypotheses must be accountable.[2] Popper's characterization of background knowledge is such, in fact, that it is difficult to pinpoint what is not included in this set of statements (e.g. refuted hypotheses form part of our "traditional knowledge" which is also part of our background knowledge[3]). Still, this picture of background knowledge is essential to Popper's version of scientific methodology since it allows for the possibility of new hypotheses being devised: One can never devise a hypothesis solely on the basis of observations, on Popper's account, so either one conjures up new hypotheses in a flash of insight or, more commonly, one constructs new hypotheses by noting the errors involved in refuted hypotheses and trying to avoid these errors while maintaining the explanatory power of the refuted hypotheses. This view is perhaps best exemplified by the following passage:

> All this means that a young scientist who hopes to make discoveries is badly advised if his teacher tells him, 'Go round and observe,' and that he is well advised if his teacher

> tells him: 'Try to learn what people are discussing nowadays in science. Find out where difficulties arise, and take an interest in disagreements. These are the questions which you should take up.' In other words, you should study the problem situation of the day. This means that you pick up, and try to continue, a line of inquiry which has the whole background of the earlier development of science behind it; you fall in with the tradition of science.[4]

This view is, of course, an expression of Popper's rejection of induction as a method of acquiring knowledge: One can not begin with observations and proceed to general assertions, for "observations are interpretations in the light of theories."[5] The correct picture, Popper tells us, is that we are always building upon our stock of background knowledge, new hypotheses must always grow out of the failure of other hypotheses. One may feel uncomfortable with this position since it seems at first glance that the set of background beliefs will be an inconsistent set. We find a Popperian like I. Lakatos writing that Popper's methodology "allows the 'body of science' to be inconsistent, since some theories may be 'accepted$_1$', together with their falsifying hypotheses..."[6] (Lakatos, by the way, finds this feature of Popper's philosophy of science to be quite felicitous since it supplies an argument for the Popperian thesis that the body of science can not be an object of rational belief.) The seeming inconsistency of the set of background statements is, as Lakatos notes, a trivial result of the fact that Popper wishes to include in this set not only refuted hypotheses but also the test results which refuted these hypotheses; both are elements of the traditional knowledge which scientists employ in their quest for new hypotheses.

However, it is easy to see that if the set of background beliefs is inconsistent then the selection criterion $CP(h_1,h_2)$ fails to prefer any hypothesis since, if b is inconsistent, it will always be the case for any two hypotheses h_1 and h_2 that $1-p(h_1,b)=1-p(h_2,b)=0$. Here the introduction of the "fine structure" values for the probability expressions will not help at all. The rule for applying fine structure values states that if two probability values differ in the short run then we assume they differ in the long run. But here, the value of $p(x,b)$, for any x whatsoever, is always one.

Popper could remedy this difficulty by abandoning any reference to background knowledge and dealing exclusively with the initial content of hypotheses. Indeed, since the value of empirical content functor "$C(h_1)$" can be calculated in non-probabilistic terms--by means of the dimension of h_1, or the set of potential falsifiers--all talk of probabilities could be eliminated. The selection criterion $CP(h_1,h_2)$ would then depend on a comparison of dimensions of hypotheses or of sets of potential falsifiers. This option seems, as we have already suggested in Chapter III, to be in conflict with the spirit of the Improbability Argument. And we find a confirmed Popperian like Watkins arguing vigorously that background knowledge is essential if the concept of corroboration is to be meaningful.[7] But more importantly, if this option is carried out, and if background knowledge is excluded from consideration, the same sorts of objections which were made concerning Hempel's assumption of zero background knowledge could be repeated against Popper's corroborability relation.

The background beliefs and information which are presupposed by a scientist when he confronts rival hypotheses surely must have an effect on his employment of a selection criterion based on confirmation. Popper's exlicatum of comparative corroborability in a limited sense captures that influence. As our examples in the first part of this chapter were constructed to show, the effect which background knowledge--theoretical frameworks, auxiliary hypotheses and so forth--has upon hypotheses and evidence is complex and various. It is possible, given a much more detailed account of the relationship between background knowledge and hypotheses and evidence, that this effect could be captured by means of probability statements. A detailed discussion of this possibility is beyond the scope of this thesis. But as Popper's account stands, the most that probability expressions capture of this relationship is the "degree of entailment" between background knowledge and hypotheses and evidence. Moreover, if Popper wishes to include refuted hypotheses as well as refuting evidence in the background knowledge then he must at least indicate how the hypotheses can be modified so that the resulting set of background statements would not be inconsistent.

We will return to the question of the role of probability expressions in the language of $CP(h_1,h_2)$ after we consider the "stronger-preferring" characteristic of $CP(h_1,h_2)$.

The outcome of our discussion of the "weaker-preferring" characteristic of $CF(h_1,h_2)$ might be such as to lead us to suspect that, in some circumstances, Popper's claim that stronger hypotheses are at least as A-acceptable as weaker ones seems justified. However, the more general claim can be easily shown to be false: What Popper likes to call the "boldness" of strong hypotheses is not always a sufficient nor a necessary reason for A-acceptance.

It is easy to see that for any genuine hypothesis "bolder" versions of it can be devised. Consider the hypothesis:

h_o Whenever a nerve cell is in a steady (nonconducting) state the cell is slowly diffusing ions through its membrane.

We may immediately construct "bolder" versions of this hypothesis, viz:

h_{p1} Whenever a nerve cell is in a steady state, or it is flooded with sodium ions, the cell is slowly diffusing ions through its membrane.

h_{p2} Whenever a nerve cell is in a steady state, or nearby cells are dividing, the cell is slowly diffusing ions through its membrane.

h_{p3} Whenever a nerve cell is in a steady state, the cell is slowly diffusing ions through its membrane and all ravens are black.

According to the criterion provided by $CP(h_1,h_2)$ all three bold hypotheses h_{p1}, h_{p2}, h_{p3} are automatically more, or at least as corroborable and therefore at least as A-acceptable as hypothesis h_o. In the case of h_{p1} there may be some evidence which indicates that the presence of sodium ions in abundance in nerve cells in fact leads to the slow diffusion of ions across the cell membrane; and in this case it may be reasonable to suggest that this hypothesis is at least as A-acceptable as h_o. But as for the other two hypotheses, especially h_{p3}, we would not likely agree with the judgment of the corroborability criterion that they are at least as A-acceptable as h_o. It is surely not the case that "bolder" hypotheses are never more A-acceptable than weaker hypotheses; but when these stronger hypotheses are more A-acceptable we will doubtless have other reasons for making that judgment.

As with $CF(h_1,h_2)$ we become suspicious when rival hypotheses can be devised at will from any hypothesis; and our suspicion becomes more acute when it is shown that these "cheap" hypotheses are always at least as preferable, or in Popper's case, as A-acceptable as the original hypothesis. Since both explicata point to purely formal aspects of scientific hypotheses--as statements expressible in formal languages--it should not be surprising that this is so: It is quite a simple procedure to manipulate expressions in symbolic languages without ever engaging in scientific pursuits. Popper is at once more cautious than Hempel about the activity of working with formal properties of statements to devise more A-acceptable hypotheses, and more careless. In the first place he is concerned in his theory of corroboration to place restrictions on the forms of hypotheses and evidence statements--restrictions which grow out of unformalizable requirements such as the involvement of "severe testing procedures". But at the same time he is careless enough to suggest that a single formal property of hypotheses, namely their "boldness", is both a necessary and a sufficient reason for their A-acceptance.

We can now turn our attention to the language of $CP(h_1,h_2)$. Since Popper does not present his theory of corroboration in the purely syntactical manner that Hempel did, it is not clear whether the problems which result concerning translating scientific hypotheses and evidence into the symbolism of predicate calculus can be pinned on Popper's explicatum as well. But given that $CP(h_1,h_2)$ is defined in terms of probability expressions we may consider the question of the applicability of these expressions in the solution to the problem of A-acceptance.

As the relation $CP(h_1,h_2)$ has been devised, we surely are left with the question of how the values for the relative probability $p(h_1,b)$ (or the values for the initial probability $p(h_1)$) can be calculated. Enough has been said in Chapters III and IV to indicate that Popper has no generally applicable formula for computing these values. Whenever Popper deals with concrete examples of hypotheses and background knowledge the question of how the probability expression $p(h_1,b)$ is to be calculated is put aside in favor of certain informal arguments. These arguments attempt to show that, when the question of choosing between hypotheses is at issue, the hypothesis which is a direct consequence of the background knowledge is always less A-acceptable than the hypothesis which is "bolder", more innovative, and generally less in accord with previously established hypotheses and previously gathered evidence. But the informal arguments translate poorly into the workings of his corroboration functor since these formulas do not seem to be applicable without definite values being assigned to specific expressions. In the case of the comparative corroborability relation we have, first, informal arguments to the effect that hypotheses with low probabilities relative to background knowledge are always more A-acceptable; and second, little in the way of a plan for the calculation of these probability values.

When Popper deals with specific cases--when for example he explains how his corroboration captures his informal requirements--he consistently employs the logical interpretation of the probability calculus, such that the degree to which one statement is a logical consequence of another is reflected in the value of the relative probability expression. But, other than noting the limiting cases, where h_1 follows directly from b, or where $\sim h_1$ follows directly from b, nothing else is said. We are left, in the case of $CP(h_1,h_2)$ with a formula which can not be evaluated in actual cases.

It might be supposed that in fact Popper does not need actual values for his probability expressions in order to determine if one hypothesis is more corroborable than another. That is, it seems plausible to argue that if Popper can induce an ordering on the hypotheses to be compared then a choice between them could be made just in terms of this ordering alone. To consider this claim we may look at the two expressions $C(h_1 e,b)$ and $C(h_2,e,b)$ (where the evidence e is the same in both expressions), as well as Popper's definition of the corroborability functor:

$$C(h,e,b)= \frac{p(e,hb) - p(e,b)}{p(e,hb)-p(eh,b)+p(e,b)}$$

By means of simple transformations we may give the definitions of the expressions $C(h_1,e,b)$ and $C(h_2,e,b)$ as follows:

$$\text{I. } C(h_1,e,b)= \frac{p(e,h_1b) - p(e,b)}{p(e,h_1,b)-((p(e,h_1b)(p(h_1,b))+p(e,b)}$$

$$\text{II.} C(h_2,e,b)= \frac{p(e,h_2b) - p(e,b)}{p(e,h_2b)-((p(e,h_2b)(p(h_2,b))+p(e,b)}$$

Now if we let $A=p(e,h_1b)$, $A'=p(e,h_2b)$, $B=p(h_1b)$, $B'=p(h_2,b)$, and $C=p(e,b)$, we may note that the expressions A, B, and C and A', B', and C are independent of each other except for certain limiting cases, e.g. if $p(e,b)=0$ then it must also be the case that $p(e,h_1b)=p(e,h_2b)=0$. Moreover, it can be shown that if $A=A'$ then either $C(h_1,e,b) < C(h_2,e,b)$ or $C(h_1,e,b) > C(h_2,e,b)$ or $C(h_1,e,b)=C(h_2,e,b)$ as $B < B'$ or $B > B'$ or $B=B'$; and similarly if $B=B'$. However, it is not always the case that if A, A', B, B', and C are all ordered with respect to each other that we may be able to determine how $C(h_1,e,b)$ and $C(h_2,e,b)$ are related to each other without access to the precise numerical values of the different probability expressions. Consider the case where the ordering on the expressions is as follows: $A < A' < B'=C$. Now consider the following assignment of numerical values to these expressions:

A	A'	B	B'	C	$C(h_1,e,b)$	$C(h_2,e,b)$
.5	.4	.2	.9	.3	.285	.293
.9	.4	.2	.9	.3	.588	.293

We notice that the first set of values gives us that $C(h_1,e,b) < C(h_2,e,b)$, and hence that h_2 is more corroborable than h_1; and the second set of values gives us the opposite result, $C(h_2,e,b) < C(h_1,e,b)$, that h_2 is more corroborable than h_1. Both sets of values are ordered in the same way, namely $A < A' < B' < B=C$, but from this ordering alone we can not say what the ordering on the corroboration functors will be, and hence we cannot determine which hypothesis is more corroborable. Hence, the claim that Popper does not need actual values for his corroboration functor in order to determine, in general, if one hypothesis is more corroborable than another is false. However, our counter-example involves the corroboration functors operating in terms of the same evidence. With different evidence for h_1 and h_2 the chances that one could induce an ordering on the corroboration functors knowing the ordering of the expression involved would be considerably reduced. In general then, it is not possible to determine if one hypothesis is more corroborable than another unless one has the absolute magnitudes of the probability expressions involved. But, once again, Popper does not provide a technique for getting these values. Consequently, it would appear that $CP(h_1,h_2)$ is wholly inapplicable and thus useless as far as the scientist's requirement for an adequate selection criterion is concerned.

So, whereas the Confirmatory Framework's explicatum seems to rest upon a formal surrogate of confirmation, one which is removed from the complexities of actual cases, Popper's explicatum is inapplicable as a selection criterion. Furthermore, Popper's explicatum of A-acceptability rests upon a view of scientific methodology which recognizes only one goal for scientists to seek, the goal of devising hypotheses which are increasingly "bolder". This restrictive view of what science aims at can be traced to the Improbability Argument which we may now criticize in some detail.

We first recapitulate the argument setting out its various parts in more detail:

(1) The aim of science, and the goal of scientists, is to "Describe 'our particular world'"[8] as precisely as possible, or equivalently, to provide the most satisfactory explanation.[9]

(2) Describing (or explaining) "our particular world" involves hypotheses which single out the world of our experience from the class of logically possible worlds.[10]

(3) Each such hypothesis "permits" only what is the case and "forbids" the rest.

Hence: (4) Eliminating logically possible, but false, descriptions of the world by refuting hypotheses is a necessary condition for arriving at hypotheses which are better and better descriptions of the world.

Hence: (5) The critical approach, i.e., always trying to falsify hypotheses on hand, is the proper methodological tactic for science.

(6) The higher the relative probability of a hypothesis with respect to background knowledge the less is forbidden and the more permitted and the less said; and

(7) The lower the relative probability of a hypothesis with respect to background knowledge the more is forbidden, the less permitted and the more said.[11]

Hence: (8) "The scientist is most interested in theories with a high content."[12] That is, the scientist is most interested in hypotheses with low relative probability with respect to background knowledge.

Consequently: The critical scientist always A-accepts that hypothesis which is lowest in relative probability and hence highest in empirical content.

That this argument is central to Popper's thinking can be seen by noting that testability/falsifiability and corroborability are all functions of empirical content. Popper's quantitative notion of corroboration goes beyond the perspective given by this argument in one respect only: The degree of corroboration of a hypothesis is a function not only of the hypothesis' relative content but also of its successes with respect to "severe" tests. But, as far as Popper's conception of the second question of A-acceptability is concerned, all that is required of a hypothesis for it to be A-acceptable is that it have a high relative content (and not be already refuted).

The first part of the Improbability Argument, steps (1) to (5), rests on premise (1) which asserts that science is just description, or explanation. From there the claim is made that hypotheses describe by singling out aspects of "our particular world". It is, first of all, puzzling that Popper should take describing to be explaining. Unless Popper is using "description" in some technical sense, which is nowhere specified, it is merely a confusion to assert that all descriptions are explanations. In the case of causal explanation Popper writes:

> To give a causal explanation of an event means to deduce a statement which describes it, using as premises of the deduction one or more universal laws, together with certain singular statements, the initial conditions.[13]

But then one may describe something without at the same time explaining it, i.e., one may describe something without carrying on a deduction from universal laws and initial conditions: Not every description is an explanandum (although every explanadum is a description) and surely not every description is an explanans. But even if we suppose that Popper just means "explanation" when he says "description" we are left with the claim that the only function of scientific hypotheses is that of explanation. And it is this claim which may be challenged.

We have already noted in Chapter II that the move from hypotheses to predictions is not wholly deductive since in most cases certain non-demonstrative steps are required. (See p.14 above.) But the role played by hypotheses in providing what I. Scheffler has called the "predictive base"[14] is a central one in the methodology of science. But, since Popper does not acknowledge the validity of non-demonstrative inference, he can not account for the role of hypotheses in providing predictive bases. That Popper's conception of the function of scientific hypotheses can not fully accommodate the notion of prediction (without giving up his all-important rejection of non-demonstrative inferences) may be sufficient to show that the Improbability Argument as a whole is unsound. However, we may find it more in keeping with our interests in A-acceptability to approach the argument from a slightly different perspective.

According to Popper the "boldness" of a hypothesis is just the likelihood of the hypothesis being refuted. In line with this Popper occasionally speaks of hypotheses as "conjectures" which, because of their innovativeness, make the growth of scientific knowledge possible. By putting all of the emphasis on the function of hypotheses to explain phenomena, and by requiring that scientists always seek out and A-accept those hypotheses which have a greater relative content (see steps (8) and (9)), Popper seems to be suggesting that the only concern of science is the continuing growth of knowledge. We read, for example:

> I assert that continued growth is essential to the rational and empirical character of scientific knowledge; that if science ceases to grow it must lose that character. It is the way of its growth which makes science rational and empirical....[15]

Because of this preoccupation with the growth of scientific knowledge, Popper insists that scientists must always be concerned with hypotheses which "say" more, those which extend our knowledge of the world and which are always open to refutation. This emphasis on the continuing growth of science, on the headlong pursuit after more innovative hypotheses, is understandable given the epistemological background of Popper's view of scientific, or more generally, rational investigation. It is in fact essential for Popper that the methodology of science be a continual search for new hypotheses, for coupled with a rejection of induction is a refusal to believe that any hypothesis is reliable, "at least in the sense that we shall always do well, even in practical action, to foresee the possibility that something may go wrong with our expectations."[16] Knowledge is always conjectural for Popper, and in his view it is the result of a psychological need for a belief in the regularity of nature that we mistakenly hold that we have good reasons for relying on the truth of certain scientific statements. Moreover, Popper holds that we can never be content with our present knowledge if we are content because we believe that what regularities are noted today will be regularities tomorrow. That regularities seem to be discovered in nature fools us into believing that some regularities are _a priori_:

> There are many worlds, possible and actual worlds, in which a search for knowledge and regularities would fail. And even in the world as we actually know it from the sciences, the occurrance of conditions under which life,

> and a search for knowledge, could arise--and succeed--seems to be almost infinitely improbable. Moreover, it seems that if ever such conditions should appear, they would be bound to disappear again, after a time which, cosmologically speaking, is very short.[17]

On the basis of this view of knowledge--and Popper's philosophy of science is rightly seen against the backdrop of this view--the only hope we have of acquiring knowledge about our world is a function of the continual growth of knowledge. But here "growth" can not be assumed to be an acquiring and retaining of more or less reliable information; rather the growth of knowledge of which Popper speaks is a process of constantly trying out new views and explanations of the world and attempting to refute them. Given this framework, there is reason to suppose that our best chance for acquiring knowledge involves the presentation of more and more innovative and bold hypotheses--to make the inevitable task of refuting them easier.

Without the Popperian view that we can never have reliable knowledge at least one other goal of science is evident, one which Popper holds to be chimerical. This other goal is that of the prudent concern for noting regularities, i.e., our concern for reliability. Scientists are concerned with the maintenance and managing of the information on hand by making more precise claims about what regularities are noted. And, as far as the growth of science is concerned, scientists are also concerned to devise more innovative and perhaps initially more probable conjectures which, if true, would enable them to extend their knowledge about specific problems to wider areas and more general problems. Both of these goals figure into the problem of A-accepting hypotheses; but Popper's error (which is, once again, only an error outside of the context of the epistemology he is offering) lies in supposing that the scientist is only concerned with the project of pushing out beyond the boundaries of his present knowledge by testing new, innovative and revolutionary hypotheses when he wishes to A-accept one or another rival hypothesis.

We would like, then, to make a distinction between the "growth" and the "extension" of scientific knowledge in the following way. It is Popper's conception of the progress of science that it is built on the premise that scientific knowledge must be continually brought into question by means of stronger, or "bolder" hypotheses put forward for the purpose of challenging the hypotheses in terms of which this knowledge was accumulated and organized. The Popperian scientist thus "aims high"--if he is interested in the growth of science he must challenge hypotheses regardless of how successful they seem to have been in the past. On the other hand, we are arguing that although this process clearly fits into any conception of scientific activity, it is by no means all that progress in science amounts to. In conjunction with the goal of pushing the frontiers of science outward is the activity of extending the information on hand that is based on those hypotheses which scientists have reason to suspect are reliable. Hence, another goal of the scientist is to, in one sense, "aim low" by filling in whatever gaps there may be in established theories, the accumulation and organization of reliable information.

What we have said above sheds light on the nature of the decision situation associated with A-acceptability. The scientist who is faced with the problem of choosing between rival hypotheses is not always in the position of the seventeenth-century scientist faced with a choice between Harvey's hypothesis and Galen's classical view. Nor is every decision situation notable for the presence of a Lavoisier, Darwin or an Einstein. When the problem of A-acceptability does involve the revolutionary crisis imposed on a science by hypotheses like those of the aforementioned scientists, the decision situation is a dramatic one, but it is not a common one. Not every decision situation follows the pattern of a new and revolutionary hypothesis facing head-on an entrenched or classical view, nor could every decision situation follow this pattern. Commonly, hypotheses present slight and subtle modifications of existing views about very specific areas in science. And it is not always the task of the scientist to devise great and innovative schemes for explaining the available data which are not in the tradition of existing hypotheses. Yet Popper seems to be insisting that that is what theoretical scientists should do. Were this the case science would never be in the possession of organized and accumulated information, but would rather leap from hypothesis to hypothesis in an endless search for the single true description of the world.

If hypotheses reflect the task of accumulating and organizing available data then the problem of A-acceptability involves such hypotheses as well as those which attempt to put whole areas of science in a new light. Yet, since it is one aim of science to break the bonds of old traditional views and to seek the more exciting hypotheses, this aim must have its influence on the scientist's concerns about deciding between hypotheses. The selection criterion which Popper has offered does not fit the purposes of A-acceptability for the reason that it presupposes a very limited notion of science's aims. But Popper's criterion of improbability may succeed with regard to the problem of B-acceptability: The problem of devising formal means for recognizing those hypotheses which are worthy of further consideration.

In the context of B-acceptability it is reasonable to suppose that a scientist may be concerned to consider as a viable alternative to existing hypotheses one which, although improbable given the present available information, would be a giant step forward in the state of the science. This is to say that scientists may have a general concern for "bolder" hypotheses. Since the purpose of B-acceptability is that of determining which hypothesis is worthy of further consideration, the object of future testing, it is quite plausible that Popper's criterion is a sufficient condition for B-acceptance. A scientist would never be led astray by B-accepting a "bold" hypothesis since his acceptance of it is only partial and is contingent upon the support or lack of support which available, or future, evidence gives to the hypothesis. It does seem true, as Popper frequently states, that "bolder" hypotheses tend to expand the range of experimentation, since tests of the "bold" hypothesis may call attention to connections between apparently unrelated aspects of a science which otherwise might not have been noticed. However, for just the reasons that Popper's criterion is unsuitable for A-acceptability, the criterion of "boldness" in hypotheses would not be a suitable necessary condition for B-acceptance.

To B-accept a hypothesis is to bring forward a plausible alternative hypothesis or a likely candidate for further consideration. But then B-acceptance is independent of the process of confirming a hypothesis. Indeed, although confirmability, developed along the lines of Hempel's conception of confirmation, is prima facie an equally adequate sufficient condition for B-acceptance, the concept of confirmation need not play an integral role in the decision to B-accept a hypothesis. A hypothesis may be B-accepted without ever being tested, confirmed or disconfirmed by new evidence or available evidence. Conversely, a hypothesis may be confirmed by a new or available evidence without having been previously B-accepted. The reasons a scientist may have for B-accepting a hypothesis may not include the confirmation which evidence has provided it. And this is particularly true in the case of Popper's criterion where the hypothesis B-accepted on the basis of its improbability relative to the background information would be that hypothesis which was least likely to be confirmed by available evidence.

It is the nature of B-acceptability that a decision to B-accept a hypothesis can be made in terms of a formal feature of the hypothesis and reflects the belief on the part of the decision-maker that the hypothesis may show itself to be of interest to science as work in the area continues. The decision to A-accept a hypothesis is motivated by the scientist's concern to choose between two or more rival hypotheses which have been tested. No assumption of the likelihood of the future success of A-accepted hypotheses needs be built into the selection criteria, although it may be.

Popper seems straightforwardly to be addressing himself to the concerns of B-acceptability: Because "bolder" hypotheses are more likely to be refuted they are valuable since they direct the object of future tests and demand that crucial experiments be devised the outcomes of which will always help the scientist in later choices. Furthermore, "bolder" hypotheses are better competitors, they aid the scientist in rooting out the errors in other hypotheses. In short, Popper's view is that since it is very likely that all of our hypotheses will be in time refuted it is necessary to choose hypotheses which, for purely formal reasons, will be found to be false more quickly and possibly in interesting ways. But this is just a possible solution to the problem of B-acceptability: Popper is offering a purely formal property of hypotheses--improbability relative to background knowledge--which determines the worth of hypotheses for future concerns.

So far we have attempted to show that both explicata, $CF(h_1,h_2)$ and $CP(h_1,h_2)$, are unsatisfactory as explicata of selection criteria for the A-acceptability of hypotheses. In the case of the Confirmatory Framework's explicatum it was shown that the formal relation of satisfaction which one kind of statement (the evidence) bears to another kind of statement (the hypothesis) is only a formal surrogate of confirmation and blurs certain complexities and overlooks some important subtleties. In the case of Popper's explicatum it was shown that, owing to various epistemological views which Popper insists upon, the explicatum is unsuitable for a selection criterion of A-acceptability, although it constitutes a plausible basis for B-acceptability. We may conclude by generalizing some of our criticisms so as to respond to two more general questions: (1) "What would an adequate formal selection criterion based on the notion of confirmation be like?" (2) "Can a single criterion theory of A-acceptability be suitable for the scientist's purposes?"

On the basis of all of our negative remarks concerning the two confirmatory logics we have considered here, it would be reasonable to respond to the first question by saying that an adequate explicatum of confirmation would be one which was responsive to the complexities found in real situations and was, moreover, workable. The drift of each of our criticisms of the two confirmatory logics has been to point out subtleties which are obfuscated by the explicata and to indicate the difficulties which arise when the different criteria are applied. Since the difficulties with each confirmatory logic were traced to either an overly-simplified picture of hypotheses and evidence (as well as their relation to background information) or a conception of scientific method which was limited to quite unique sorts of hypotheses, the proper preparation to a formal explication of confirmation would be a better understanding of how "confirmation" is used and understood by scientists. Towards this end an analysis of the notion of confirmation is needed which is sufficiently complete so that formal reconstructions of confirmation do not fall into the kinds of traps that we have set in this chapter.

By way of a response to the second question, we may take another look at Popper's theory of acceptability (i.e., what he has supposed to be a theory of A-acceptability). Here it is not that we are not supplied with several criteria for basing a choice among hypotheses, for Popper mentions several criteria--among them simplicity, non-ad-hocness, empirical content, testability, improbability, and corroborability. But as it happens none of these features of hypotheses are, on Popper's account, independent of the single criteria of improbability. Although Popper explicitly equates corroborability only with improbability, as we saw in Chapter III each of the other features of hypotheses can be seen to be functions of the improbability of hypotheses. We would like to argue that theories of A-acceptability based on a single selection criterion, or for which all the mentioned selection criteria are interdependent (or interdefinable) are, generally speaking, unsuitable for the scientist's purposes.

To support this last claim we might begin by noting that the question of what selection criteria a scientist could employ to choose between hypotheses is as much of a matter for empirical investigation as is the question of choosing between hypotheses. When a philosopher provides a set of selection criteria, whether the set consists of only one or a dozen criteria, there may be the assumption that further empirical investigation will not determine that some other set of criteria provides, in the long run, a better basis for choice. But this is a false assumption, since at bottom the value of selection criteria, and the success of a theory of A-acceptability, is a function of the fruitfulness of the resulting A-accepted hypotheses. Hence, minimally a theory of A-acceptability must be such that the specified set of selection criteria is itself answerable to evidence reporting the successfulness or unsuccessfulness of the theory's designated choices.

Secondly, it can be argued that a single criterion basis for any choice tends to limit the variety and multiformity of that which is chosen. If, for example, our single criterion for choosing which art object will find a place in a museum is that of realism then after a time our museum will contain only realistic works of art. Analogously, if we were to adhere to a single criterion theory of A-acceptability after a time all of the hypotheses available to us would reflect this single criterion. In Popper's case it is conceivable that science would cease to be an organized body of knowledge if science's theory of A-acceptability consisted of the single criterion of "boldness".

Finally, since the problem of A-acceptability is a practical problem, it is a problem concerning particular cases of conflict between rival hypotheses. As such, the problem of A-acceptability is contingent upon what the scientist wants a hypothesis in some area of science to accomplish. It is realistic to grant the scientist the option with regard to undecidable conflicts whether to resume empirical investigation or to bring another selection criterion to bear on the question. If it happens that two hypotheses are equally A-acceptable with respect to one selection criterion, the scientist may decide that this criterion reflects the sought after property of hypotheses concerned with some field of application or he may decide that another criterion, or another set of criteria, reflects the requirements he places on such hypotheses. But, of course, since the scientific activity is an objective and cooperative one, individual scientists can not provide the final word on the standards by which their hypotheses are to be judged.

In short then, single criterion theories of A-acceptability at best have limited usefulness and at worst may fail to provide standards for judging hypotheses in certain ways. Moreover, it is indeed possible that science is not homogeneous in the sense that scientists in such diverse fields as Physics and the Social Sciences may require different criteria by which to judge the hypotheses they are interested in. And if this is so, then the problem of A-acceptability, like the problem of providing a satisfactory explication of confirmation, seems to wait on an analysis of the notion of "hypothesis" as scientists in different branches of science use and understand the word. In any event, however, the difficulties with the confirmatory logics which we have attempted to draw out in this thesis point to the complexities which are at issue in the question of hypothesis preference and A-acceptance, and it is only by meeting these complexities head-on that any hope of an adequate theory of A-acceptability can be secured.

FOOTNOTES TO CHAPTER V

1. Hempel, "Postscript (1964) On Confirmation," in Aspects of Scientific Explanation, pp.49-51.

2. Popper, Conjectures and Refutations, pp.112, 238-40, 288 and 390.

3. Popper, Conjectures and Refutations, pp.27-8 and 238.

4. Popper, Conjectures and Refutations, p.129.

5. Popper, Conjectures and Refutations, p.38 fn 3. Compare (The Logic of Scientific Discovery, p.106): "...if I am ordered: 'Record what you are now experiencing' I shall hardly know how to obey this ambiguous order. Am I to report that I am writing; that I hear a bell ringing; a newsboy shouting; a loudspeaker droning; or am I to report, perhaps, that these noises irritate me? And even if the order could be obeyed: however rich a collection of statements might be assembled in this way it would never add up to a science. A science needs points of view, and theoretical problems."

6. I. Lakatos, "Changes in the Problem of Inductive Logic," in The Problem of Inductive Logic, ed. I. Lakatos, p.383. Lakatos' notion of 'acceptance$_1$' (which seems to mean 'adding to our stock of knowledge') is a suitable sense of acceptance to fit in with Popper's conception of background knowledge.

7. J.W.N. Watkins, "Confirmation, the Paradoxes, and Positivism," p.111.

8. Popper, The Logic of Scientific Discovery, pp.113 and 114.

9. Popper, The Logic of Scientific Discovery, p.114; and "The Aim of Science," p.24.

10. Popper, The Logic of Scientific Discovery, p.113.

11. Popper, The Logic of Scientific Discovery, pp.41, 119, and 399; and Conjectures and Refutations, p.286.

12. Popper, Conjectures and Refutations, p.286.

13. Popper, The Logic of Scientific Discovery, p.59.

14. I. Scheffler, The Anatomy of Inquiry, pp.46-57.

15. Popper, Conjectures and Refutations, p.215.

16. Popper, "Conjectural Knowledge: My Solution of the Problem of Induction," p.188

17. Popper, "Conjectural Knowledge: My Solution of the Problem of Induction," p.189.

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